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PHOTO INDUSTRIAL STUDY No. 9

THE COPPER, LEAD, AND ZINC INDUSTRIES

UNITED STATES FORCES

OFFICE OF THE ASSISTANT CHIEF OF AIR STAFF, INTELLIGENCE, HQ. U. S. ARMY AIR FORCES AND PHOTOGRAPHIC INTELLIGENCE CENTER, DIVISION OF NAVAL INTELLIGENCE, NAVY DEPARTMENT, JULY 1945

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ACKNOWLEDGMENT

Acknowledgment is made to the various offices in the War and Navy Departments and to other government agencies who have furnished valuable information on Japanese metallurgical facilities. The domestic copper, lead and zinc industries have been of great assistance by supplying many of the photographs and much of the technical data incorporated in this study.

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FOREWORD

Stepped-up strategic bombing of the Japanese economic war potential, has created increased demands upon the photographic interpreter for information concerning war production industries. To assist photo interpreters in the field in meeting these greater demands, a series of Photo Industrial Handbooks is now being prepared describing the fundamentals of important war industries. The following study dealing with the copper, lead, and zinc industries is the seventh handbook in the series.

Each Photo Industrial Study is designed primarily to provide interpreters with the essential data needed to identify industrial plants and their basic processing components. Secondarily, each study is intended to supply some background data for the analysis of plant construction, the assessment of plant construction, the assessment of bomb damage and the post-raid analysis of plant repair

To implement the presentation of its fundamentals the main divisions of the Copper, Lead and Zinc Industrial Study have been sub-divided into sections dealing with (a) processes and equipment used in each stage of production, (b) distinguishing features that will help identify the plants in which the various processes take place, (c) the construction and vulnerability to bombing of important units within each type of plant.

Detailed sections describing plant processes and equipment have been included because experience has proved that distinguishing features above are insufficient for complete and consistent identification of industries. The ideal layout of a modernized metallurgical plant will reflect the logic of the flow sheet. Hence, a familiarity with plant processes will sometimes enable the photo interpreter to identify the important buildings that channel this flow, even when their exterior design is of common industrial type.

Section V describes briefly the chamber and contact process of producing sulphuric acid. This description is presented merely to show the relationship of sulphuric acid manufacture to copper, lead, and zinc smelting. It is not intended to be a complete study of the sulphuric acid industry.

Sections of the study dealing with plant vulnerability are designed to acquaint the photo interpreter with the key installations present at each plant he studies. This knowledge will aid him in placing the proper emphasis upon the facts he reports. It is not expected that the photo interpreter will be equipped to draw conclusions from these facts such as estimating the plant production loss or the time required for repairs. Such conclusions are outside his province.

Similarly, it is not expected that all information for the analysis of enemy war industries will come from aerial photographs. In practice enemy plants are identified and analyzed by a combination of ground intelligence and photo intelligence. Often photos of enemy plants merely confirm data that is already known, and only in a few isolated instances do they give all of the details known about a plant. Because of this natural and necessary relation between aerial photographs and ground information, a ground intelligence section summarizing the basic data now known about important Japanese copper, lead, and zinc producing facilities has been added at the end of the handbook.

Comments and critiscisms of this study and its purposes are invited from photographic interpreters engaged in operational work in industrial interpretation.

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PHOTO INDUSTRIAL STUDIES

ISSUED

NO. 1 NITROGEN
NO. 2 PETROLEUM
NO. 3 COKE, IRON, AND STEEL
NO. 4 ALUMINUM
NO. 5 AIRCRAFT
NO. 6 EXPLOSIVES
NO. 7 SHIPBUILDING
NO. 8 MAGNESIUM
NO. 9 COPPER, LEAD, AND ZINC.

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INTRODUCTION

WARTIME IMPORTANCE OF COPPER, LEAD, AND ZINC

Copper, lead, and zinc are raw materials essential to any nation engaged in modern war. The importance of these metals lies in the capacity of copper to conduct electricity and heat, the immunity of both copper and zinc to rust, and the resistance of lead to the action of weak acids.

Copper forms the wire and cable needed to operate the complex electrical equipment used in mechanized military vehicles, war production machinery, electronics installations, aircraft, and shipping. Copper and zinc alloyed to form brass provide a material uniquely adapted to the manufacture of ammunition and ordnance parts. Zinc is used universally for galvanizing to protect the surfaces of such objects as machine parts mess gear, and corrugated iron construction sheeting. Lead, in war, is employed primarily in projectiles for small arms ammunition, non-corrosive pipe and covering for cables, battery plates, alloys, pigments and linings of acid chambers.

Deprived of copper, lead, and zinc no nation could long meet the heavy material demands imposed by war.

GENERAL NATURE OF METALLURGICAL INDUSTRIES

Processes employed in the production of copper, lead, and zinc fall within a general pattern of operations that is common to nearly all metallurgical industries. Initially, the raw materials are "mined" from natural deposits in the earth. The material thus recovered is then processed to extract the valuable metallic elements it contains, either by pyro-metallurgical methods (treatment with fire known as smelting) or by hydro-metallurgical methods (principally treatment with solvents known as leaching). Prior to extraction, in order to make the reduction more economical, low grade materials are sometimes crushed and concentrated (or "dressed").

The product obtained from smelting or leaching is usually too impure for direct commercial use and must be refined. After refining, the pure metal and its alloys are cast, rolled, or forged into commercial shapes to be used in fabrication. Mining, dressing, and extraction plants are ordinarily located near natural deposits of raw materials (often in isolated regions); while refining and fabricating developments are located in manufacturing districts close to markets.

JAPANESE COPPER, LEAD, AND ZINC INDUSTRIES

Japanese copper, lead, and zinc resources and industrial facilities are controlled by a few powerful combines that own not only mines, smelters and refineries, but also finished products plants. Because these corporations have consistently made a practice of hiring western technicians, all three industries are largely modern and have been quick to take advantage of new developments. Differences in Japanese resources, Japanese labor costs, and Japanese laws, however, have made it necessary to adapt western techniques to local conditions. As a result, the details of copper, lead, and zinc installations are not always the same as those found in the United States. Nevertheless, there is enough similarity between plants in the two countries to permit ready comparison.

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SECTION 1

MINING AND ORE DRESSING

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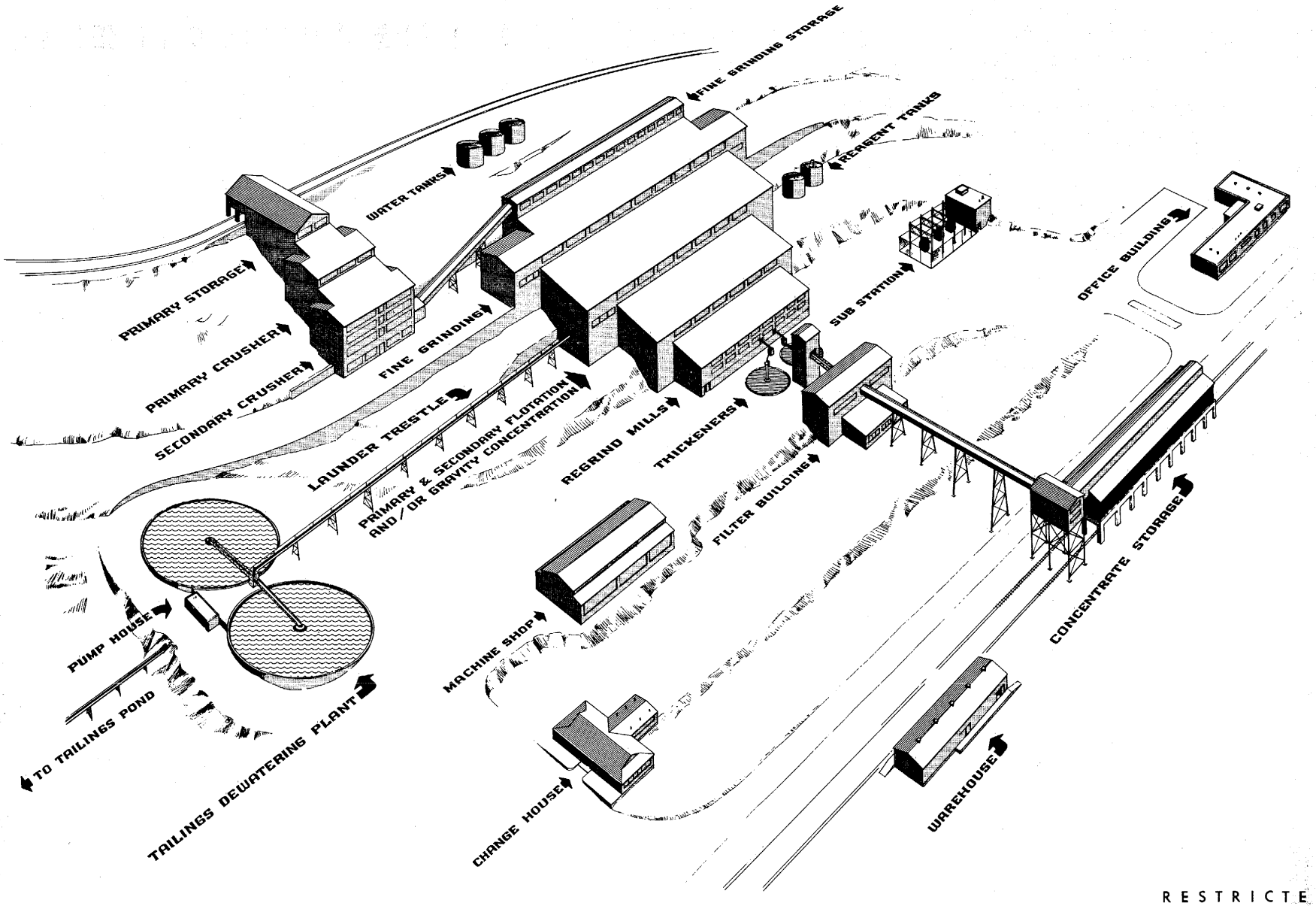
TYPICAL ORE DRESSING PLANT



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INTRODUCTION

Metallic copper, lead, and zinc are obtained from two sources (1) ores extracted from mines, and (2) scrap gathered from fabricating plants and junk piles.* Ores may be defined generally, as mixtures of valuable and waste minerals containing enough useful metal to make exploitation profitable. Variable factors such as technological improvements in process, physical characteristics of the mineral deposit, (size, shape, grade of ore, by-products etc.) labor costs, market prices, and transportation rates determine whether or not exploitation of an ore body will be profitable.

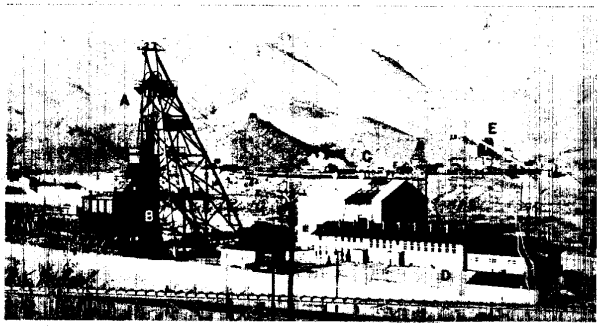
In recent years, technological improvements have outweighed other factors and have made possible the working of ores in which the primary useful metal comprises a lower and lower percentage of the total deposit. Thus, it is now economically feasible to develop low-grade copper ores that are only 0.8% copper, lead ores that contain 3.5% lead, and zinc ores that are as low as 3.0% zinc. This fact is important to remember, for although high-grade ores can be mined with simple equipment on a small scale, low grade ores must be mined on a large scale and mechanically concentrated with elaborate equipment.

Lead and zinc occur in close association in nature and are recovered almost exclusively from sulphide ores. Copper, although obtained from some important deposits of native and oxidized ores is likewise taken primarily from sulphides. In a sulphide ore, the prime metal occurs with other elements as a compound which must be chemically changed before a pure product can be extracted. For the purpose of studying Japanese copper, lead, and zinc production facilities, only the working of sulphide ores need be considered, because nearly all of the important ore deposits in the Japanese Empire are composed of low-grade sulphides.

MINING METHODS

Mining methods fall roughly into two categories, namely, underground mining and open-pit mining. In actual practice lead and zinc deposits are worked entirely by underground methods. Although some of the most important copper mines are open-pit developments, the majority of copper operations are also underground. In Japan, the only important mine known to employ open-pit methods is the aged Kosaka development in northern Honshu.

Underground Mining: Access to underground mines is gained either by vertical or inclined shafts or by tunnels. Shaft entrances are used in flat country and at mines where tunneling long distances would be too expensive. Tunnel entrances are used in mountainous country. Because Japanese mining regions are universally rugged and because of the resultant saving in hoisting and draining costs, it is likely that tunnel entrances predominate at Japanese mines.



VERTICAL SHAFT COPPER MINE - MONTANA

A - HEAD FRAME
B - ORE BIN
C - HOIST HOUSE
D - CHANGE HOUSE
E - CONCENTRATOR

LEAD AND SILVER MINE WITH CONCENTRATOR ADJACENT

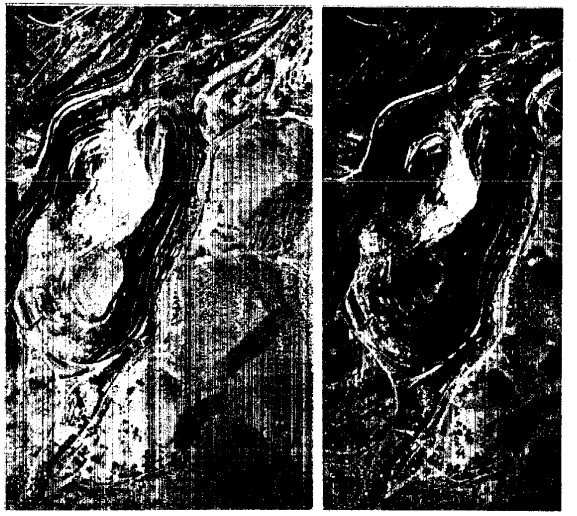
A - HEAD FRAME
B - CONCENTRATOR
C - HOIST HOUSE
D - ADMINISTRATION BUILDING
E - LUMBER YARD AND SAWMILL
F - SHOPS

VERTICAL SHAFT COPPER MINE - ARIZONA

A - HOIST HOUSE
B - CHANGE HOUSE
C - HEAD FRAME AND ORE BIN
D - BOILER HOUSE
E - VENT SHAFT AND FAN HOUSE
F - WATER TANK AND COOLER

Open-pit Mining: Open-pit mining methods are employed to recover ores which exist near the earth's surface. This type of mining consists of either "glory-hole" or "bench" operations.

"Glory-holing" is actually a hybrid of open-pit and underground methods, for although glory-holes show up as scars on the earth's surface, the ore itself is removed through tunnels or shafts.



COMBINATION GLORY HOLE AND BENCH MINE

*In countries which have been industrialized for some time, scrap is the source of a large percentage of metal production, but in Japan which has been industrialized only recently and whose economy has been on a war footing for over ten years, domestic supplies of scrap are limited. Metallurgically, once scrap has entered the stream of smelting and refining processes, it is treated in much the same way as ores.

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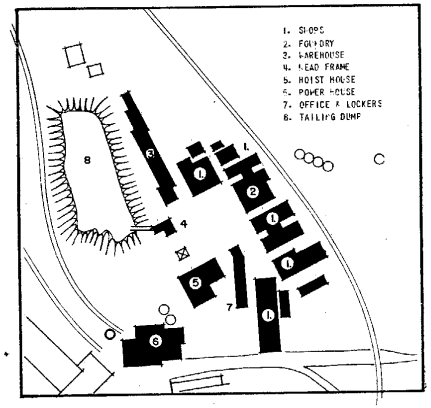
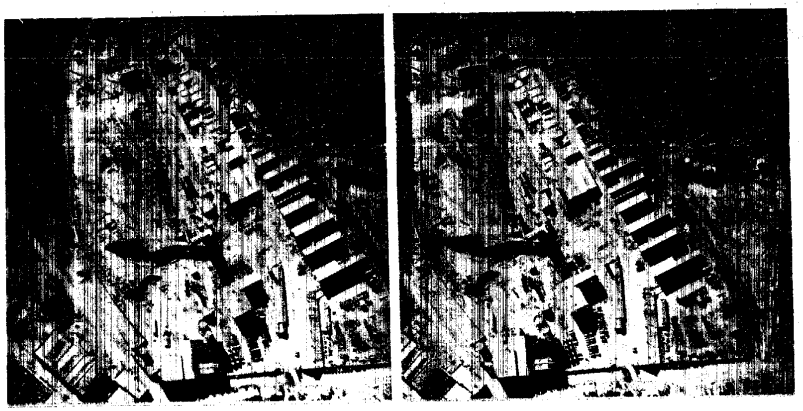
MINING AND ORE DRESSING

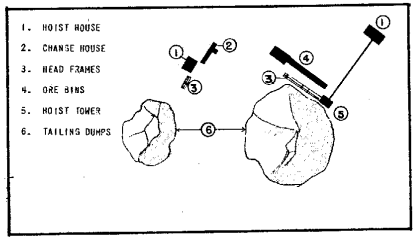
MINING METHODS

In bench mining the sides of the excavation are developed as open terraces. The ore is broken down on the terraces and removed. In small operations this removal may be accomplished by hand methods, but in large operations the broken ore is loaded by power shovels into ore trains or trucks that operate over a complex system of tracks or roads.

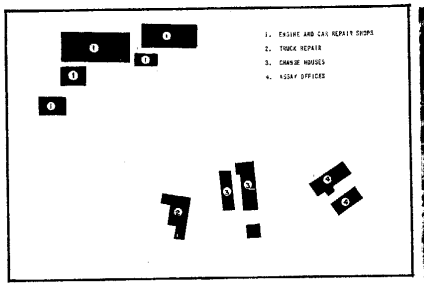


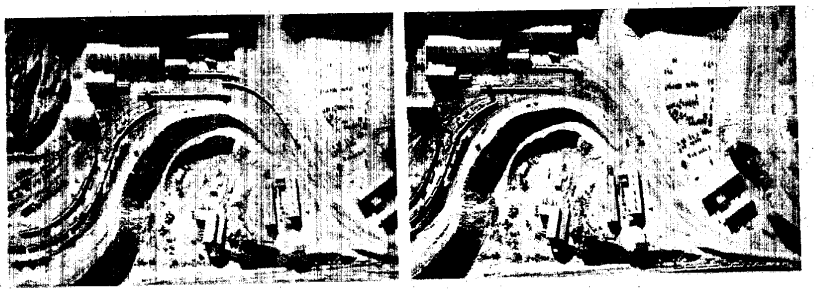


COPPER SHAFT MINE WITH AUXILIARY BUILDINGS ADJACENT



DOMESTIC COPPER MINE.





BENCH MINE AUXILIARY BUILDINGS

DISTINGUISHING FEATURES OF MINING OPERATIONS

When seeking to identify mining operations, the photo interpreter should look for the following distinguishing features.

(1) Head Frames (or shaft houses):
- (a) Present at mines served by shafts; height 50'-150'.
- (b) Grooved blocks at top for hoisting cables indicate number of shaft compartments (usually three, one for water and air pipes, electric cables and ladders, and two for hoisting and lowering miners, tools, ore and supplies.)
- (c) Hoist towers sometimes present for carrying hoisting lines from head frame to hoist house.

(2) Hoist Houses:
- (a) Alligned with long base dimension of headframes.
- (b) Distinguished by box-like structures and by hoisting cables that pass through side walls to top of headframe.
- (c) Size varies with bulk of steam or electric powered hoisting machinery contained within.
- (d) At inclined shaft-mines headframes may be lacking and only hoist houses will be apparent.

(3) Tunnel Entrances:
- (a) Present at mines entered from hill or mountain side on horizontal or gently dipping plane.
- (b) Distinguished only by point at which haulage tracks, power cables, and pipes disappear underground.
- (c) Wood or masonry archway may be apparent in in low oblique photos.

(4) Ore-Bins
- (a) Sometimes built into headframe at shaft mines where bucket conveyors are used for hoisting ore.

(5) Ore-Haulage Equipment
- (a) Usually railroad ore cars.
- (b) Where dressing mill is adjacent to mine, belt conveyors (often built below ground) or aerial trams operating on overhead cables may be used.

(6) Storage Yard
- (a) Primarily for timbers needed to support underground workings.

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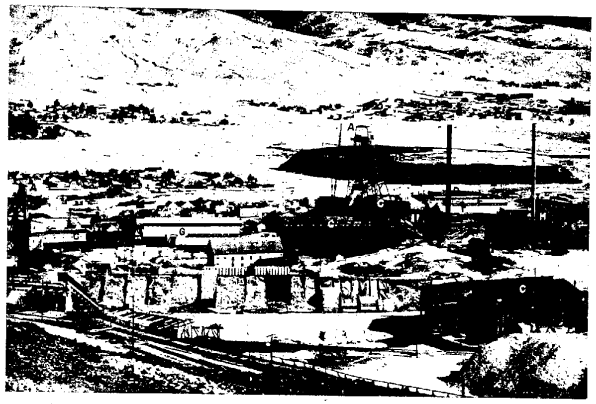
(7) Auxiliary Buildings.
  (a) May include blacksmith and machine shops for the repair of ore cars, drills, etc.; buildings housing water pumps, air compressors, and ventilating fans (if needed); testing houses for sampling ore; a saw mill; a change house (locker room) for the miners; and a power plant or transformer station.

(8) Waste Rock Dumps
  (a) Tracks lead from mine entrance to dump.

(9) Open-Pit Mines
  (a) Easily distinguished by excavation scars on earth's surface.
  (b) Other mining features (auxiliary buildings, waste dumps, headframes etc.) often visible near excavation.



DOMESTIC COPPER MINE

A - HEAD FRAME
B - HOIST TOWER
C - ORE BINS
D - HOIST HOUSE (OBSCURED)
E - POWER HOUSE
F - TIMBER STORES
G - MACHINE SHOP
H - TRESTLE TO POWERHOUSE & COAL RECEIVING BINS

ORE DRESSING

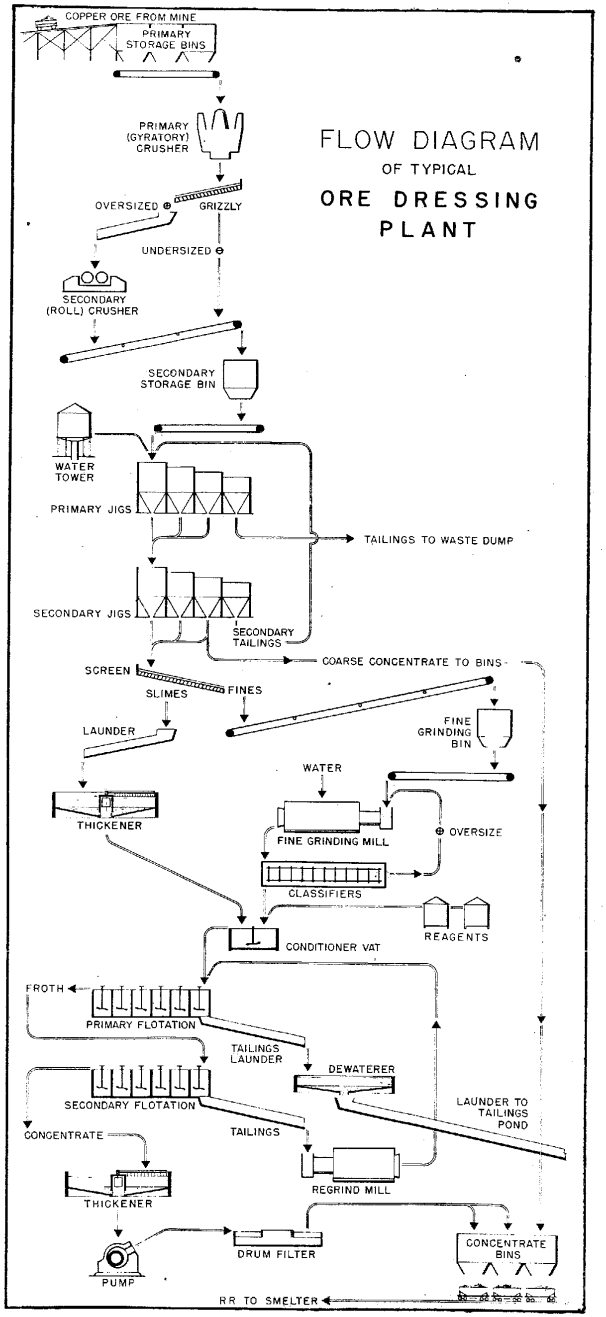
Ores as they are taken from the mine consist of a small percentage of valuable minerals mixed with a large percentage of valueless waste or "gangue". It is the purpose of ore-dressing to increase the percentage of valuable minerals by separating them from the gangue which is then discarded. Recently developed mechanical methods of ore-dressing have made such a separation possible in ores of very low grade with the result that mechanical methods are currently practiced in all the copper, lead, and zinc producing countries of the world.

ORE DRESSING METHODS

The actual stages that an ore will go through during dressing depend upon the minerals it contains and upon the size and association of its individual grains. At some mines the ore, before being sent to the mechanical dressing mill, may go through a hand sorting operation in which high grade material is manually separated on a belt conveyor from low-grade ore and waste. Generally, however, the processes employed in ore-dressing are mechanical and can be classed under two headings (1) Crushing and grinding, during which the ore is broken down into its individual mineral particles, and (2) Concentration during which the crushed particles are separated into two or more fractions.

Crushing and Grinding: Crushing and grinding operations are subdivided into three stages: (1) Primary crushing in gyratory or jaw crushers where the ore is reduced to pieces roughly 6" in diameter, (2) Secondary

AN UNUSUALLY LARGE GYRATORY CRUSHER, NOTE GRIZZLEY CLASSIFIER AT UPPER RIGHT



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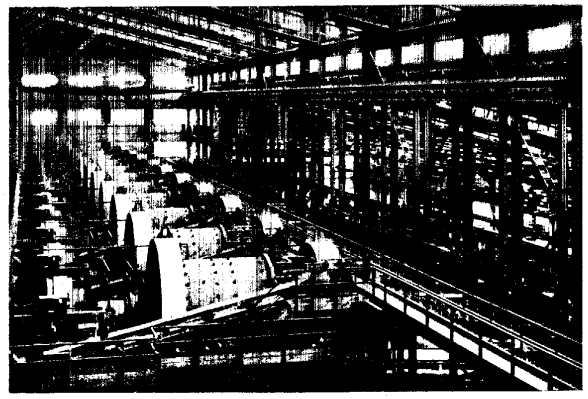
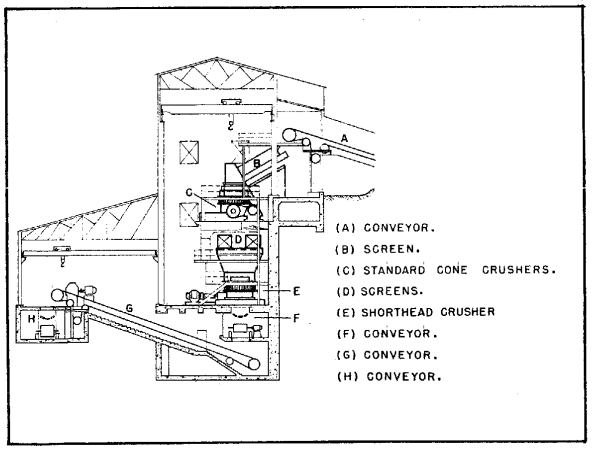
ORE DRESSING PROCESSES

crushing in disc or roll crushers which break the ore particles down to approximately 5/16 of an inch in size, and (3) Fine grinding in ball, rod, or tube mills that reduce the ore to the ultimate consistency of powder. Primary crushers handle the ore dry, secondary crushers may or may not have water added, and fine grinders almost always use water in at least equal weight with the ore.



BALL MILLS ARRANGED IN PARALLEL AT A LARGE CONCENTRATOR

Prior to and between primary, secondary, and fine grinding operations ore particles may or may not be stored in bins depending upon the individual practice at different plants. Upon leaving each crushing and grinding apparatus the pulverized ore is screened or classified and oversized pieces are returned for another pass through the machine.



SECONDARY CRUSHER BUILDING

Although a single crusher may be of sufficient capacity to handle the ore in primary crushing, in secondary crushing and fine grinding a number of machines are usually arranged in parallel. For this reason damaged equipment can be cut out of operation for repairs without disturbing the effectiveness of the remaining units. Most crushing and grinding machines are of standard design and can be used interchangeably in different plants.

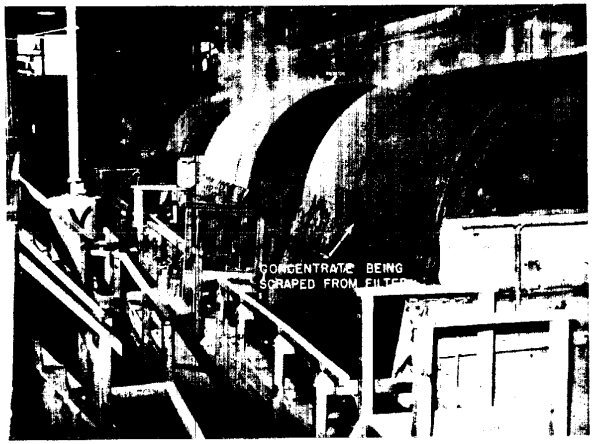
Concentration: The finely ground ore pulp goes from the crusher to the concentrator where valuable ore constituents are separated from each other and from the waste. This is accomplished by either gravity or flotation processes. In typical combination layouts gravity methods are used during the initial stages of concentration for the separation of coarse materials and flotation methods in the final stages for treating more finely divided materials.

Gravity Concentration depends for its success upon the different specific gravities of the minerals which are to be separated. Because valuable minerals for the most part have a greater specific gravity than worthless materials, the two separate when agitated in water. Gravity concentration equipment consists of either jigs or reciprocating tables. A jig is essentially a box with a screen bottom; when submerged in water and vibrated, heavy ore particles settle on or pass through this screen, while lighter materials remain on the water surface and are skimmed off. A reciprocating table has a grooved and slightly inclined surface. As the ore pulp passes over this surface, metallic particles settle in the grooves and are carried over the table end, while lighter particles stay in the stream of wash water and go directly over the side.

Flotation is by far the most effective concentration method employed in the treatment of ores. Its effectiveness depends upon the affinity of mineral surfaces for froth bubbles formed by the aeriation of solutions containing flotation reagents (commonly vegetable oils, soaps, or inorganic chemicals). When ore pulp from fine grinding mills or gravity machines is mixed with these reagents and agitated in flotation cells, the metal bearing parts of the ore adhere to the froth bubbles and are subsequently skimmed off. Waste particles remain separate from the bubbles and are drawn off cell bottoms as tailings. By using different flotation reagents, different minerals can be separated from the pulp through successive stages of differential flotation. This is a process especially effective for treating ores in which lead and zinc occur in close association.

Dewatering of Concentrates: The skimmed flotation froths and/or the wet concentrates from jigs and reciprocating tables are carried by launders (troughs) out of the concentrator building to circular thickener tanks (from 50'-100' in diameter) where recovered minerals are allowed to settle, and water is removed by overflow into a holding box. These settled minerals are in turn discharged from the thickeners through underground launders to a filter building at which they receive their final dewatering. Preparatory to final shipment, concentrates move by conveyor from the filter building to storage bins.

PRIMARY FLOTATION CELLS. NOTE OVER-FLOWING FROTH BUBBLES



DRUM FILTERS DEPOSITING THEIR CONCENTRATE CAKE ON A BELT CONVEYOR.

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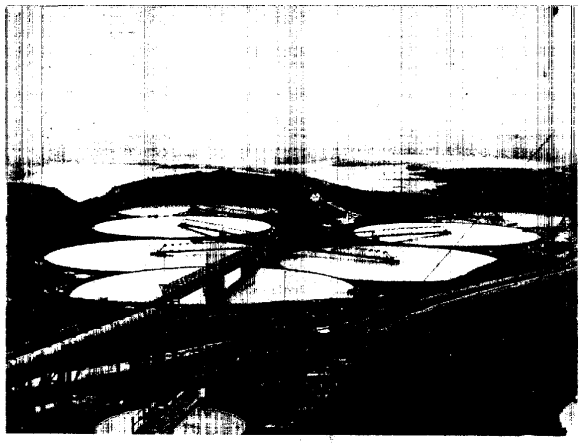
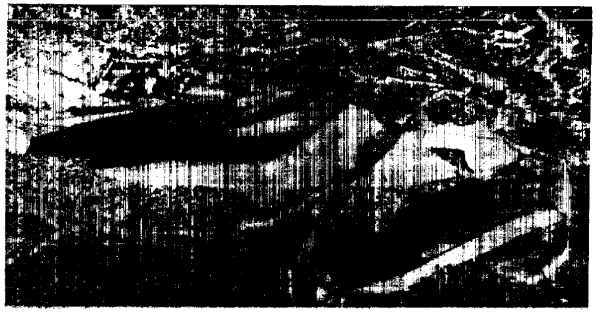
Tailing Disposal: Tailings from both gravity and flotation operations are sloughed off through launders as waste. At some mills, launders discharge into sprawling dumps or merely dump into adjacent bodies of water, but at most plants, tailings are carefully controlled (1) to recover the water present, and (2) to keep them from contaminating streams. At these mills, launders lead to large dewatering tanks (from 200'-300' in diameter) where the tailings are settled out and their



TAILING DEWATERERS AND SETTLING POND AT A LARGE CONCENTRATOR

water restored (by a pumping system) to head tanks above the concentrator. The settled sludge that remains is sent through additional launders to settling ponds where more water is recovered. At some settling ponds the sludge builds up as a tremendous whitish deposit that provides one of the best distinguishing features of the concentrator.



HILLSIDE TAILING POND WITH CONCENTRATOR IN BACKGROUND

In Japan dressing mills are generally located at the headwaters of streams that pass in their later stages through agricultural land and rice paddies. To prevent polution of these farming developments, Japanese laws strictly regulate the discharge of tailings. The rugged terrain in which most Jap mills are situated, however, limits the area in which large regulated tailing ponds can be developed. Therefore, at many Jap mills tailings are settled in large tanks which are subsequently dredged of their thickened sand and slime by overhead cranes. The dredgings are then sent by aerial tramway to adjacent waste dumps.

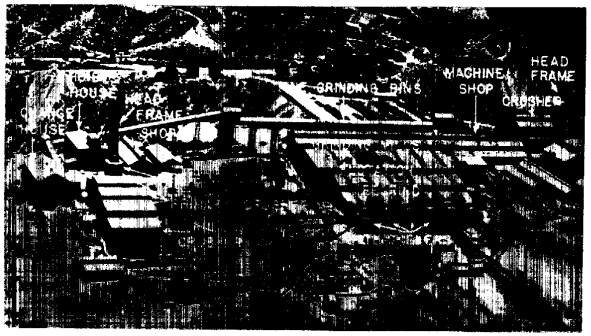
TREATMENT OF MINE WATER AT COPPER MILLS

Much of the ground water pumped from wet copper mines contains a worthwhile amount of copper in solution which can be profitably recovered by a simple process called cementation. Treatment of this water, although not technically a part of copper ore dressing, is nevertheless often carried on at the mill site. The cementation process depends upon the fact that a metal can be displaced from solution by a less noble element. Thus, if metallic iron is added to a solution of copper sulphate, the iron dissolves and metallic copper is precipated out. In commercial use of cementation, iron is loaded into tanks, towers, or launders and the mine water solution allowed to trickle slowly over its surface. Cement copper forms on the iron as a loosely adherent granular deposit which can be dislodged by shaking or washing and then flushed into settling tanks. From time to time settling tanks are excavated and the precipitate shipped to smelters for further treatment.

DISTINGUISHING FEATURES OF ORE DRESSING PLANTS

Summary of Features: To utilize the effect of gravity, ore dressing mills are commonly located on the side of a hill and as a result can be distinguished generally by the stepped roof-lines of their important crusher and concentrator buildings. Next to these main buildings, the most easily recognizable features of dressing operations are dewatering tanks and tailing dumps. Transportation lines for carrying ore to and from the mill are usually apparent leading to primary crushing facilities and away from concentrate storage bins.

The geographic location of dressing plants is influenced by economic necessity which demands that the plant be as close to its mine as possible in order to limit transportation costs. Location is similarly influenced by technical necessity which demands that the concentrator be near a steady supply of water.



COPPER MINE AND CONCENTRATOR

There is no identification formula for distinguishing dressing mills that treat copper ores from those that treat lead, zinc, nickel, or even gold and silver ores. In fact a single concentrator will often process ores which include several of these elements. Generally speaking, concentrators used exclusively for copper are larger than those used for other non-ferrous metals, but sizes will vary tremendously with the extent of the deposit being exploited and with the grade of the ore produced. Actually, the only reliable way to determine the metal processed by a concentrator is to determine the metal produced at its adjacent smelter, if there is one present.

DETAIL OF FEATURES

Crushing Facilities

(1) Crusher Buildings:
  (a) Primary and secondary crushers may be housed in two separate buildings or (more often) in a single high, narrow structure stepped in sections into a hillside;
  (b) To utilize gravity, crushers are usually sited at a higher elevation than other structures at dressing plant
  (c) Primary crusher buildings are distinguished by conveyor or railroad that delivers mined ore at their uphill ends.

(2) Storage Bins
  (a) Distinguished by relative location to concentrator and crusher buildings.
  (b) Commonly high narrow structures that are nothing more than roofed over silos.
  (c) May be reinforced concrete bins built into ground.
  (d) May be part of crusher or concentrator buildings (e.g. fine grinding bins are located in high upper step of concentrator.)

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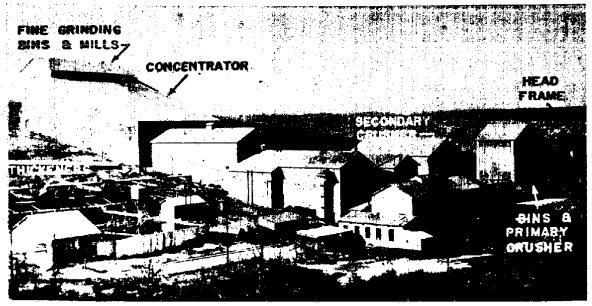
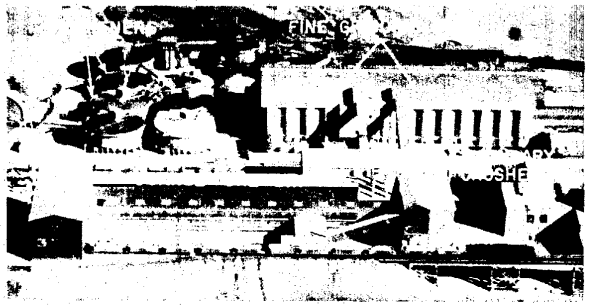
MINING AND ORE DRESSING

DISTINGUISHING FEATURES OF ORE DRESSING PLANTS



LEAD MINE AND CONCENTRATOR

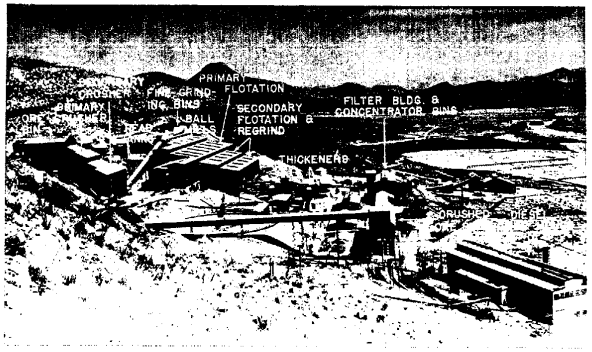


COPPER CONCENTRATOR

Concentrating Facilities

(1) Hand Picking Plant:
- (a) Probably identifiable only when built as separate unit at mine entrance.
- (b) Appearance similar to that of stepped crusher building (especially when plant contains crushing equipment of its own);
- (c) Waste dump and ore bins commonly located nearby.

BESSHI MINE, SHIKOKU, HAND PICKING PLANT

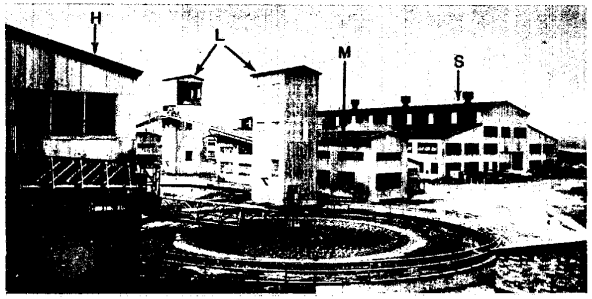


TYPICAL CONCENTRATOR - TREATS COPPER ORES

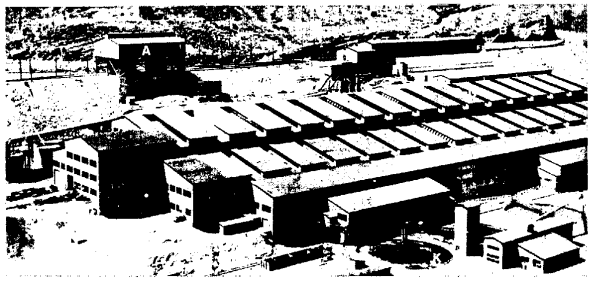
(2) Concentrator Building:
- (a) Largest structure at dressing mill; varies in length with number of jigs, tables and/or flotation cells placed in parallel within.
- (b) Exterior roof line stepped in sections into sloping ground (high upper section contains fine grinding storage bins and mills; central section holds gravity equipment and/or flotation cells; and lowest section contains regrind mills or tables for retreating high-grade tailings).
- (c) Building further distinguished by small steel tanks for flotation reagents and recovered water located along its uphill periphery.

(3) Dewatering Tanks:
- (a) Generally circular and built of concrete or wood - in Japan dewatering tanks used for tailings may be rectangular to facilitate dredging by cranes.
- (b) Thickener tanks for concentrate sludge, and settling tanks for tailings essentially the same except that the latter are much larger (Thickeners average roughly 60' in dia. and settlers from 200'-300' in dia.);
- (c) Launder trestles that spill tailings and froth into center of tanks look much like the hands on the face of a clock.
- (d) Holding box for recovered water, pump house, and pipes leading to head may sometimes be visible near dewaterers.

(4) Filter Building:
- (a) Small building (approx. 40' x 100') located at base of concentrator where it can be fed by conveyors from thickener tanks.
- (b) If building is at elevation of concentrator, elevators housed in a tower-like structure may be present for lifting concentrate sludge to filter feed hoppers.

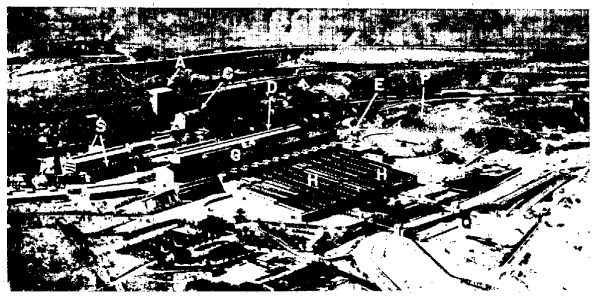


CONCENTRATE THICKENER AND FILTER BUILDING



ESSENTIAL STRUCTURES AT A LARGE MODERN CONCENTRATOR

(5) Concentrate Storage Bins:
- (a) Tall, long and narrow silo-type bins that measure 300' x 50'.
- (b) To utilize gravity, concentrate bins are located (where possible) at lowest dressing mill elevation.
- (c) Bins emptied by conveyor system if smelter is adjacent; otherwise, by railroad cars that pass under discharge hoppers in bin bottoms.



LARGE COPPER CONCENTRATOR

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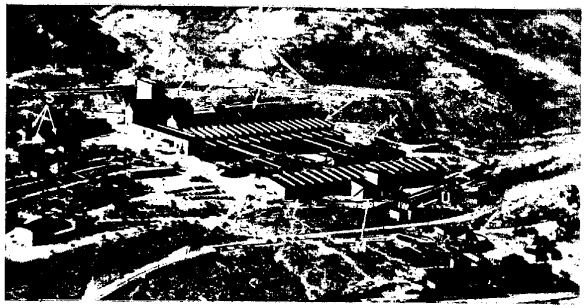
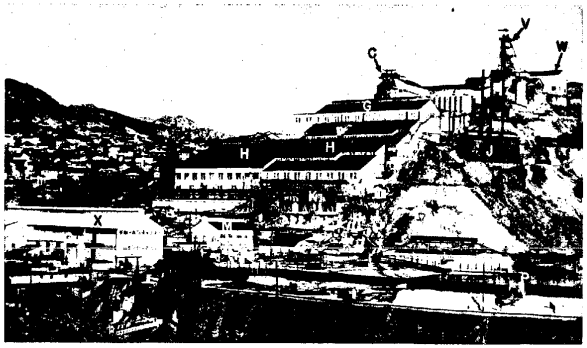
KEY TO ANNOTATED PHOTOGRAPHS

A - PRIMARY CRUSHER	M - FILTER BUILDING
B - SECONDARY CRUSHER BIN	N - FILTER PUMPS
C - SECONDARY CRUSHER	O - CONCENTRATE BINS
D - FINE GRINDING BIN	P - TAILING DEWATERERS
E - REAGENT TANKS	Q - TAILING LAUNDER
F - WATER TANKS	R - TAILING POND
G - GRINDING MILL	S - SHOPS
H - FLOTATION CELLS	T - SUB-STATION
I - DIFFERENTIAL FLOTATION	U - STEAM PLANT
J - REGRIND MILLS	V - HEAD FRAME
K - THICKENER TANKS	W - HOIST HOUSE
L - FILTER ELEVATORS	X - MINE WATER RECOVERY



LARGE COPPER CONCENTRATOR



ESSENTIAL STRUCTURES AT A TYPICALLY JAPANESE MINE AND CONCENTRATOR

Tailing Disposal

(1) Tailing pond identified by large size and limy whiteness in relation to surrounding landscape - one of the best distinguishing features.

(2) Ponds usually located in natural depressions or on hillsides near concentrator.

(3) Where terrain doesn't conform naturally to basin, sludge dams are built along pond periphery.

(4) In Japan where tailings are sometimes dredged from settling tanks, identifying features may include settling tanks and their dredging crane, a waste dump, and towers for an aerial tram operating between tanks and dump.

Auxiliary Buildings

(1) Include generally a power house or sub-station, a change house, (locker room), a concentrate sampling building, carpenter, machine and electric shops, and warehouses.

(2) Characteristics and number of auxiliary buildings vary with each mill; machine shop will usually be equipped to handle relatively heavy crushing and grinding equipment.

Mine Water Recovery:

(1) Plants normally small; may be distinguished by circular or rectangular tanks, towers, or troughs in which cementation occurs. In cold climates, tanks etc. may be roofed over and therefore indistinguishable.

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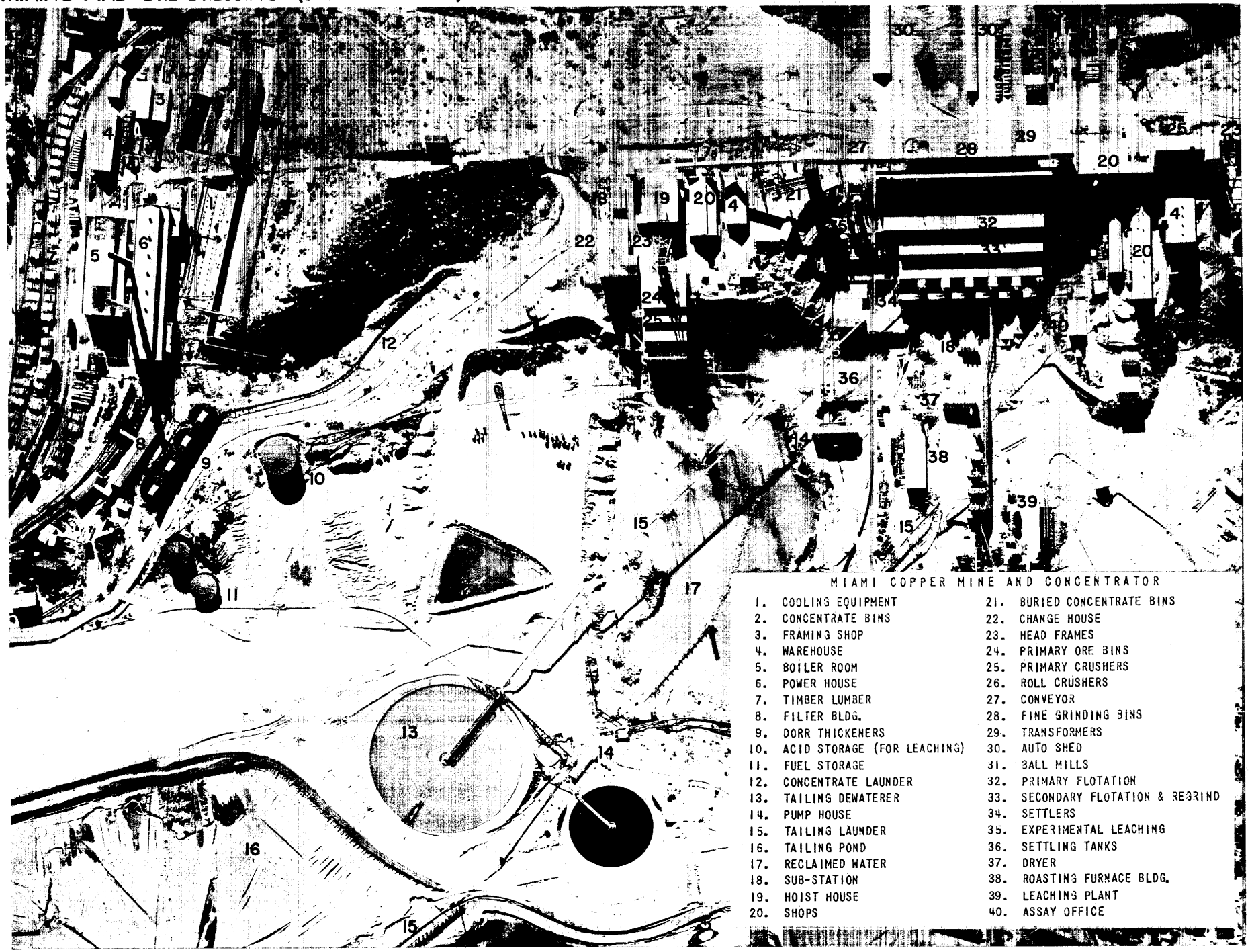

MIAMI COPPER MINE AND CONCENTRATOR

1. COOLING EQUIPMENT	21. BURIED CONCENTRATE BINS
2. CONCENTRATE BINS	22. CHANGE HOUSE
3. FRAMING SHOP	23. HEAD FRAMES
4. WAREHOUSE	24. PRIMARY ORE BINS
5. BOILER ROOM	25. PRIMARY CRUSHERS
6. POWER HOUSE	26. ROLL CRUSHERS
7. TIMBER LUMBER	27. CONVEYOR
8. FILTER BLDG.	28. FINE GRINDING BINS
9. DORR THICKENERS	29. TRANSFORMERS
10. ACID STORAGE (FOR LEACHING)	30. AUTO SHED
11. FUEL STORAGE	31. BALL MILLS
12. CONCENTRATE LAUNDER	32. PRIMARY FLOTATION
13. TAILING DEWATERER	33. SECONDARY FLOTATION & REGRIND
14. PUMP HOUSE	34. SETTLERS
15. TAILING LAUNDER	35. EXPERIMENTAL LEACHING
16. TAILING POND	36. SETTLING TANKS
17. RECLAIMED WATER	37. DRYER
18. SUB-STATION	38. ROASTING FURNACE BLDG.
19. HOIST HOUSE	39. LEACHING PLANT
20. SHOPS	40. ASSAY OFFICE

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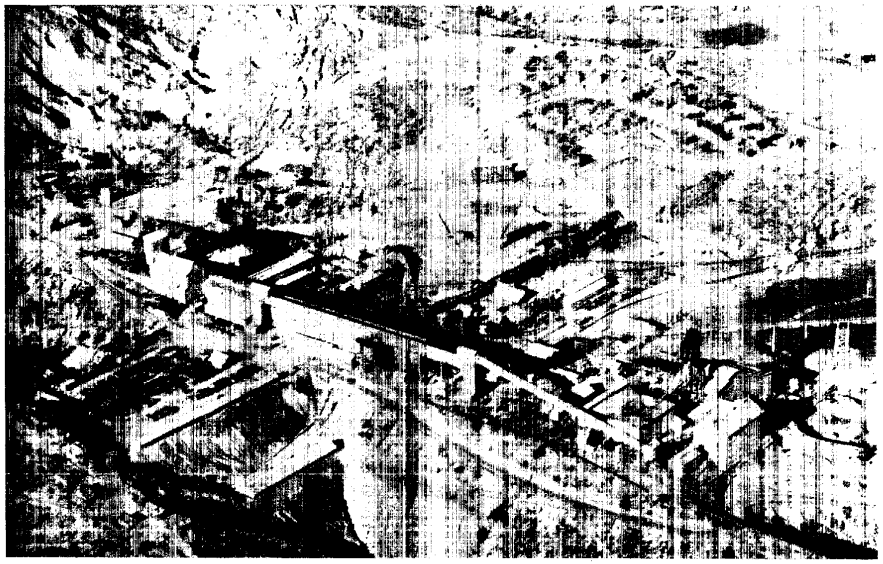
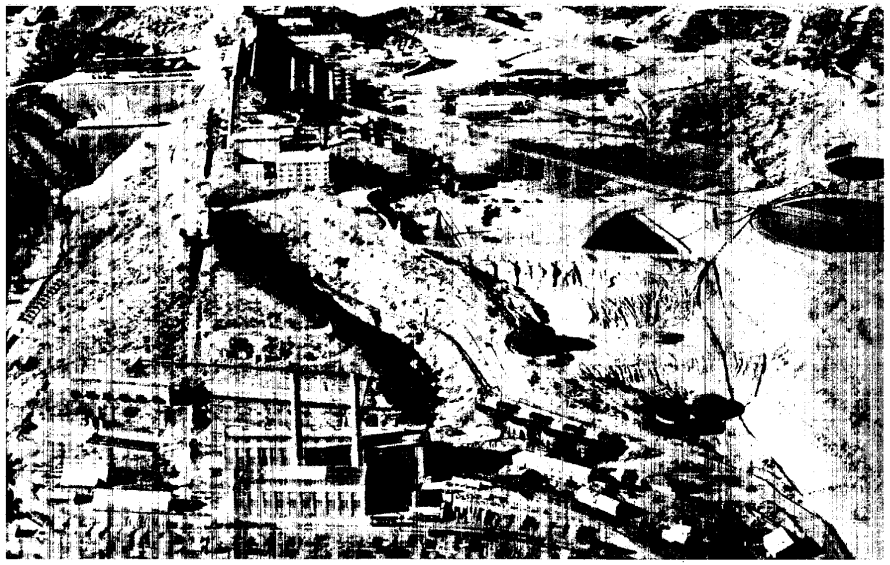
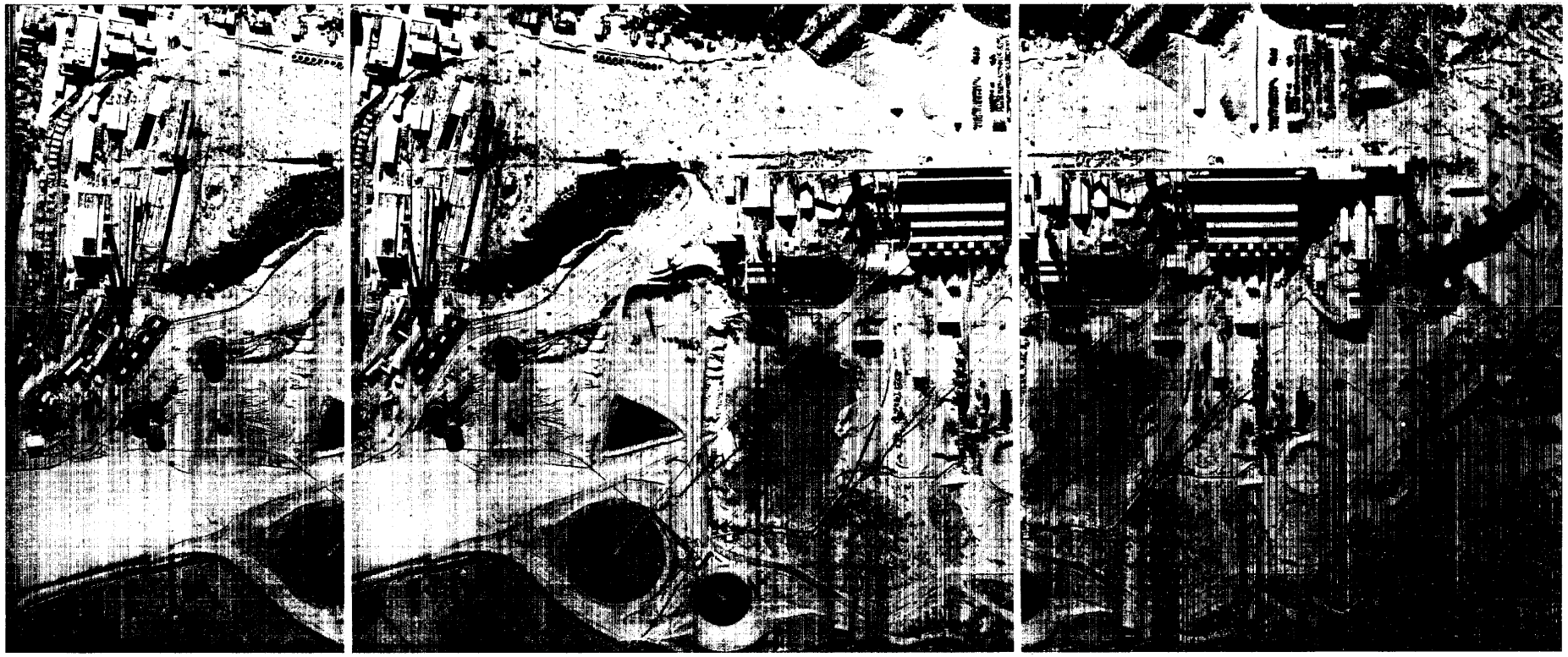




MIAMI CONCENTRATOR - OBLIQUE AND STEREO VIEWS



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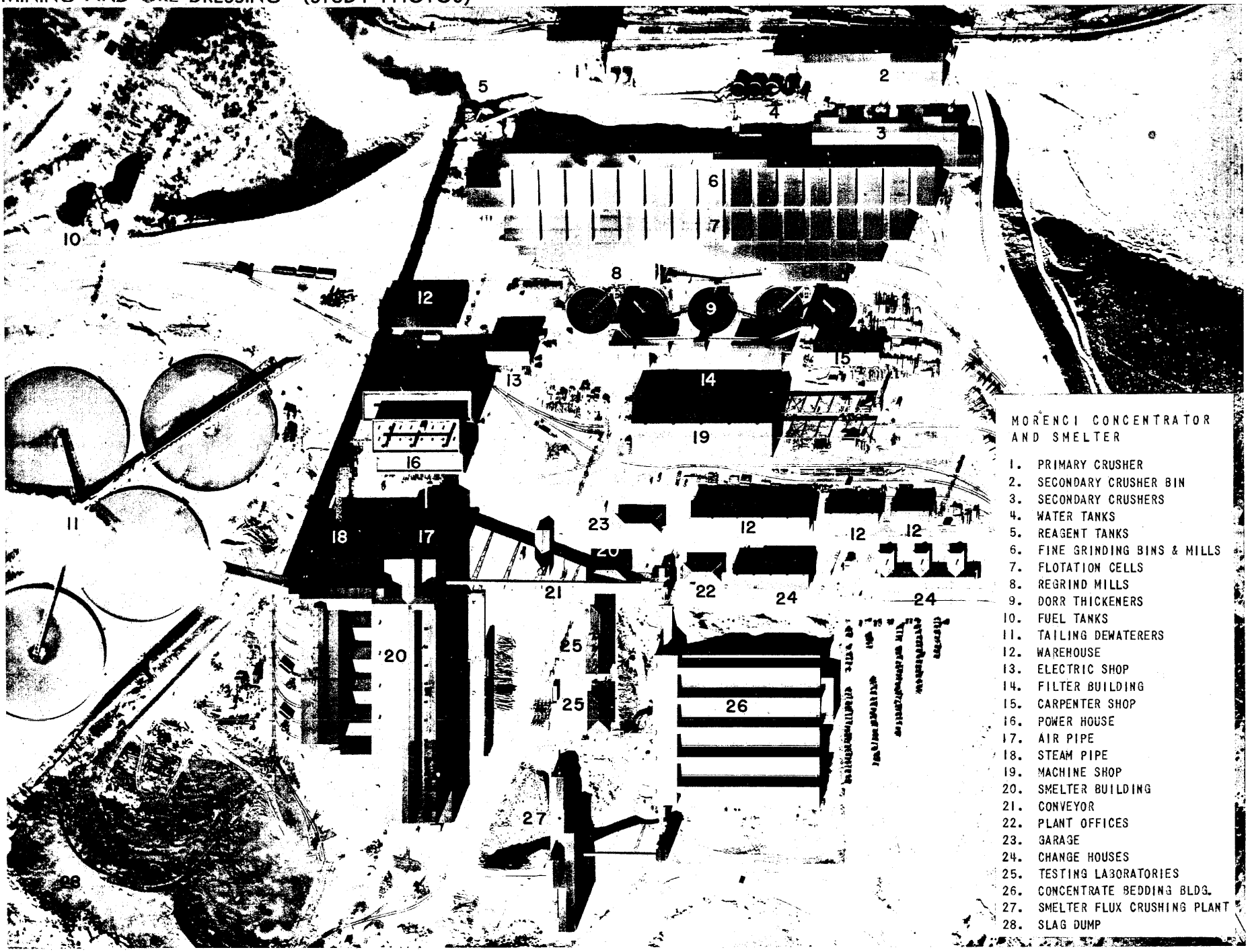

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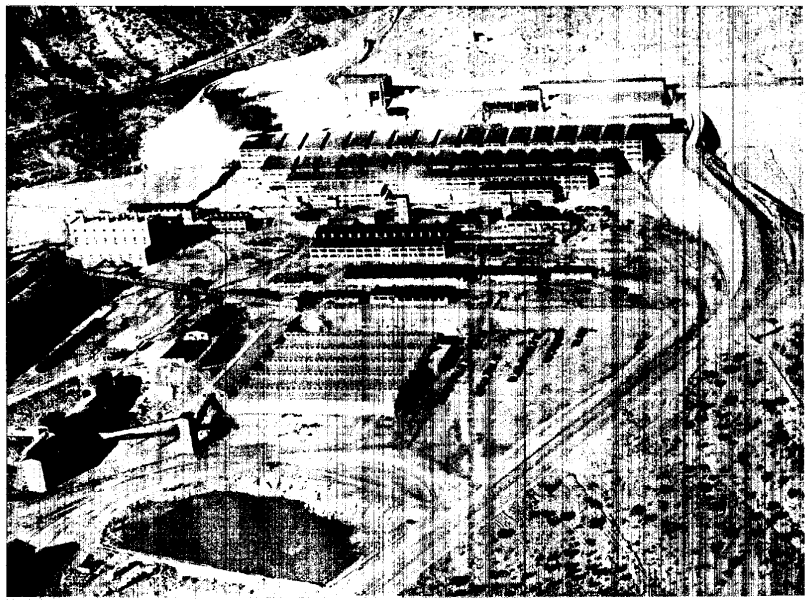
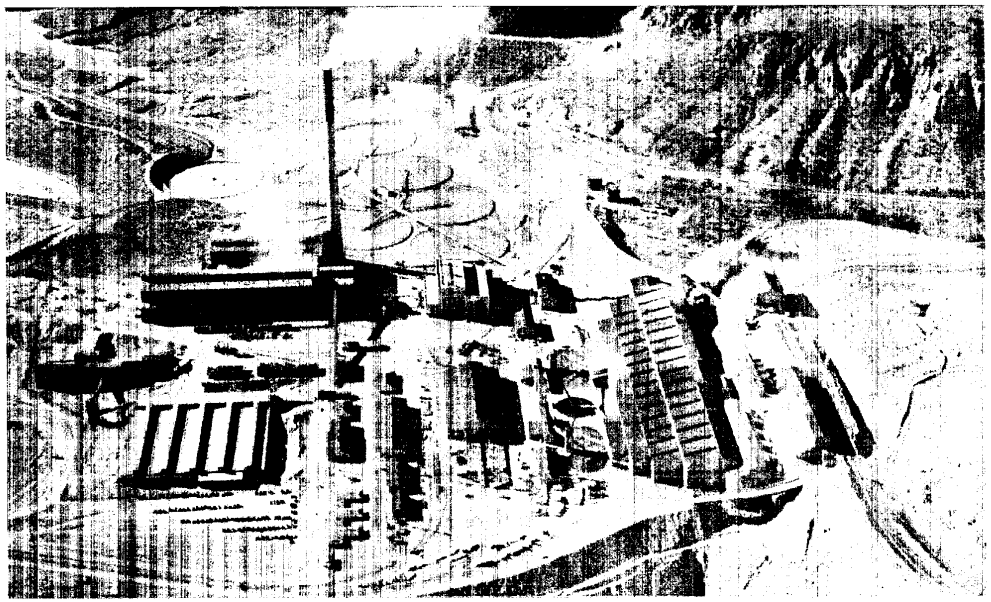
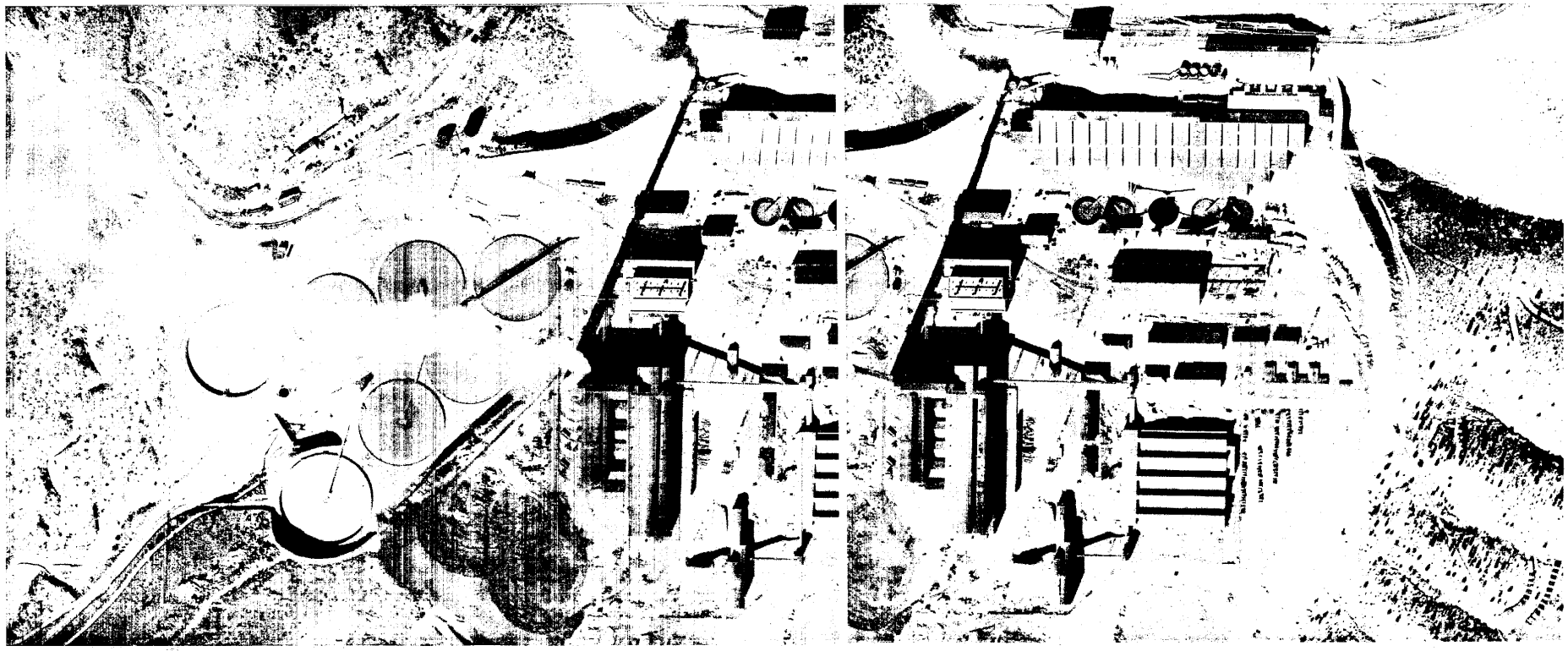




MORENCI CONCENTRATOR AND SMELTER - OBLIQUE AND STEREO VIEWS



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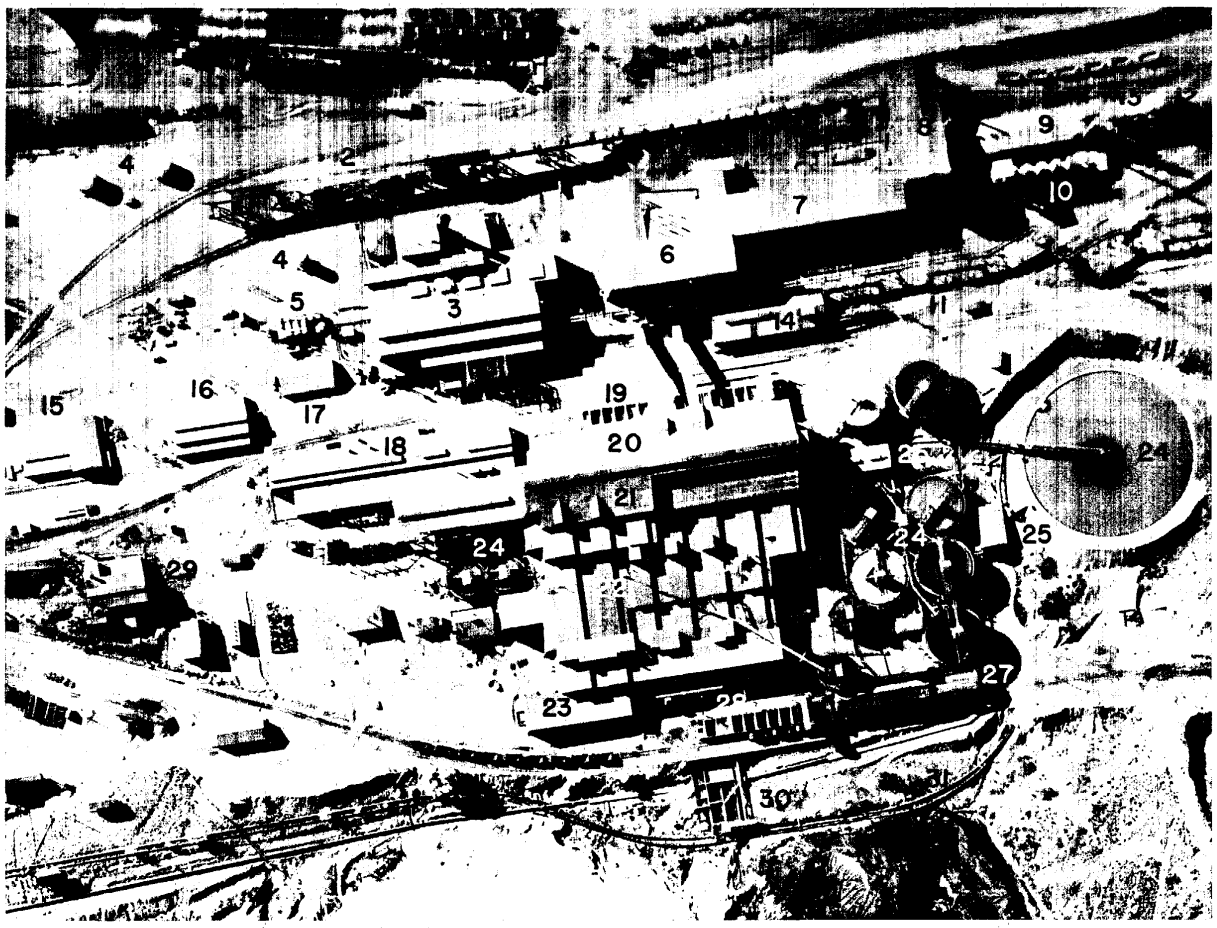
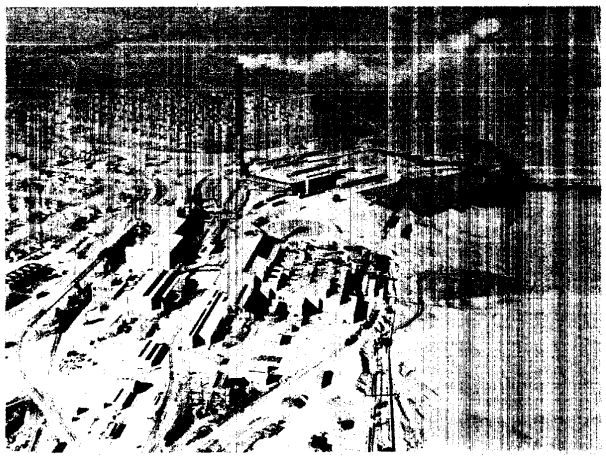
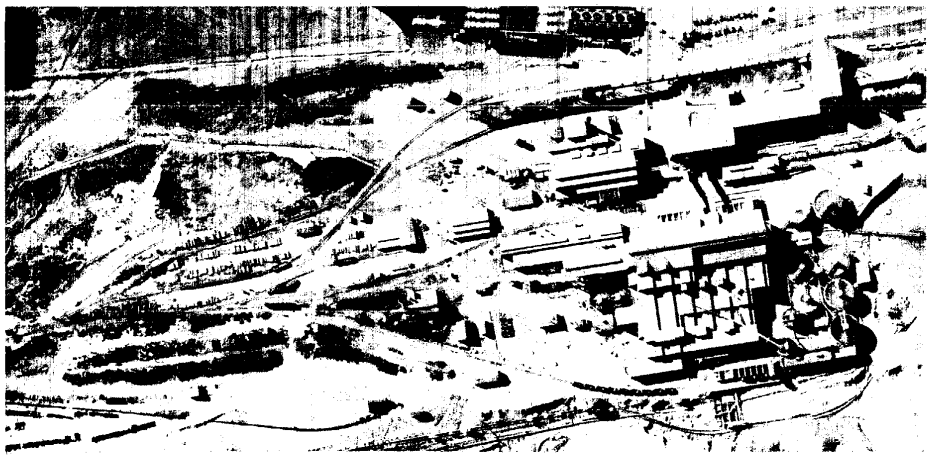
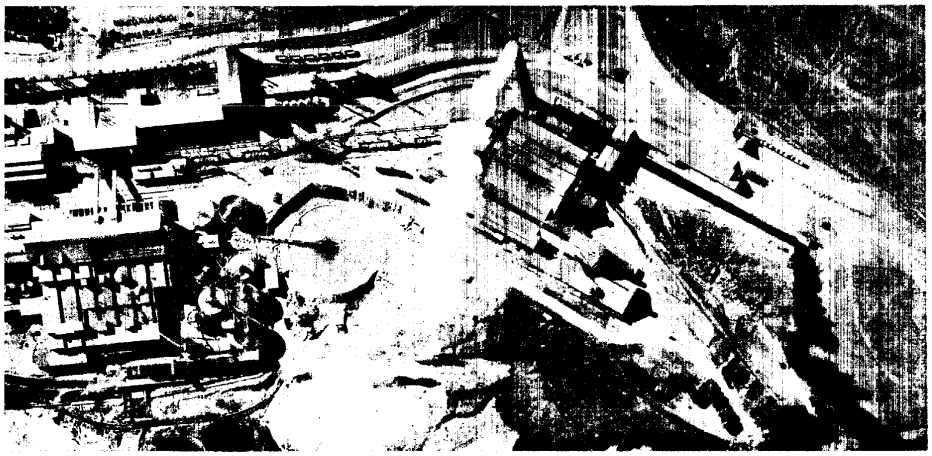




1. POWER HOUSE SPRAY POND
2. WATER TANKS
3. POWER HOUSE
4. FUEL TANKS
5. REAGENT TANKS
6. SECONDARY CRUSHER
7. COARSE ORE BINS
8. PRIMARY CRUSHER
9. ROTARY LIME KILN
10. LIME STGE. TANKS
11. STEAM & AIR BLAST LINES (TO SMELTER)
12. LIMESTONE CRUSHER
13. LIMESTONE STORAGE
14. WAREHOUSE
15. LUMBER SHED
16. CARPENTER SHOP
17. TRUCK GARAGE
18. SHOPS (MACHINE, BLACKSMITH, ELECTRIC & RIGGERS)
19. LIME CONCENTRATE BINS
20. FINE GRINDING BINS & MILLS
21. CLASSIFIERS
22. FLOTATION CELLS
23. BLOWER ROOM
24. DORR THICKENERS
25. PUMP HOUSE
26. TAILING DEWATERER
27. FILTER BLDG.
28. CONCENTRATE BINS
29. FOUNDRY
30. CONCENTRATE SUMP & SUMP RECOVERY BLDG.
31. TAILING LAUNDER

HURLEY CONCENTRATOR - OBLIQUE, VERTICAL, AND STEREO VIEWS





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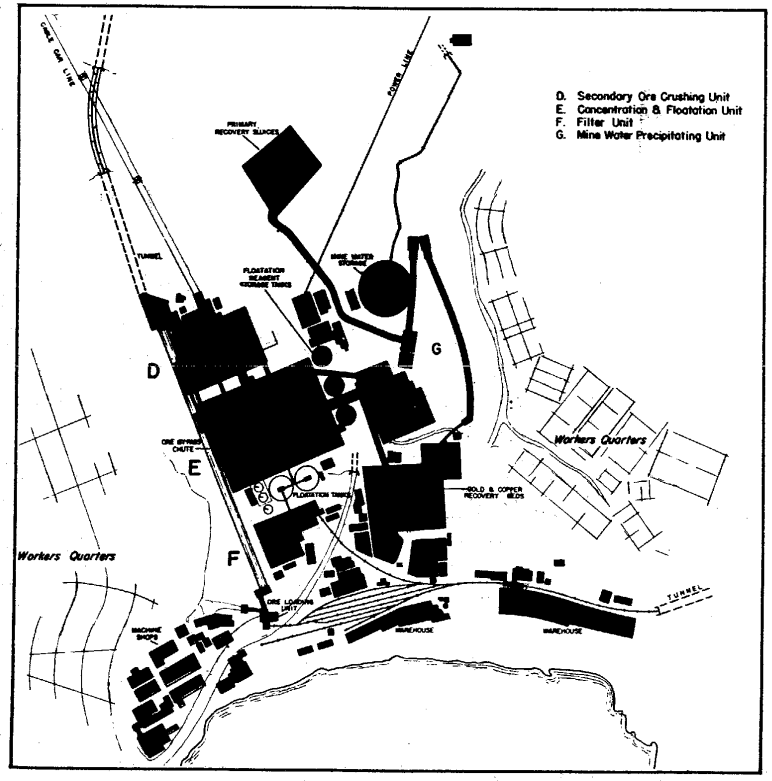
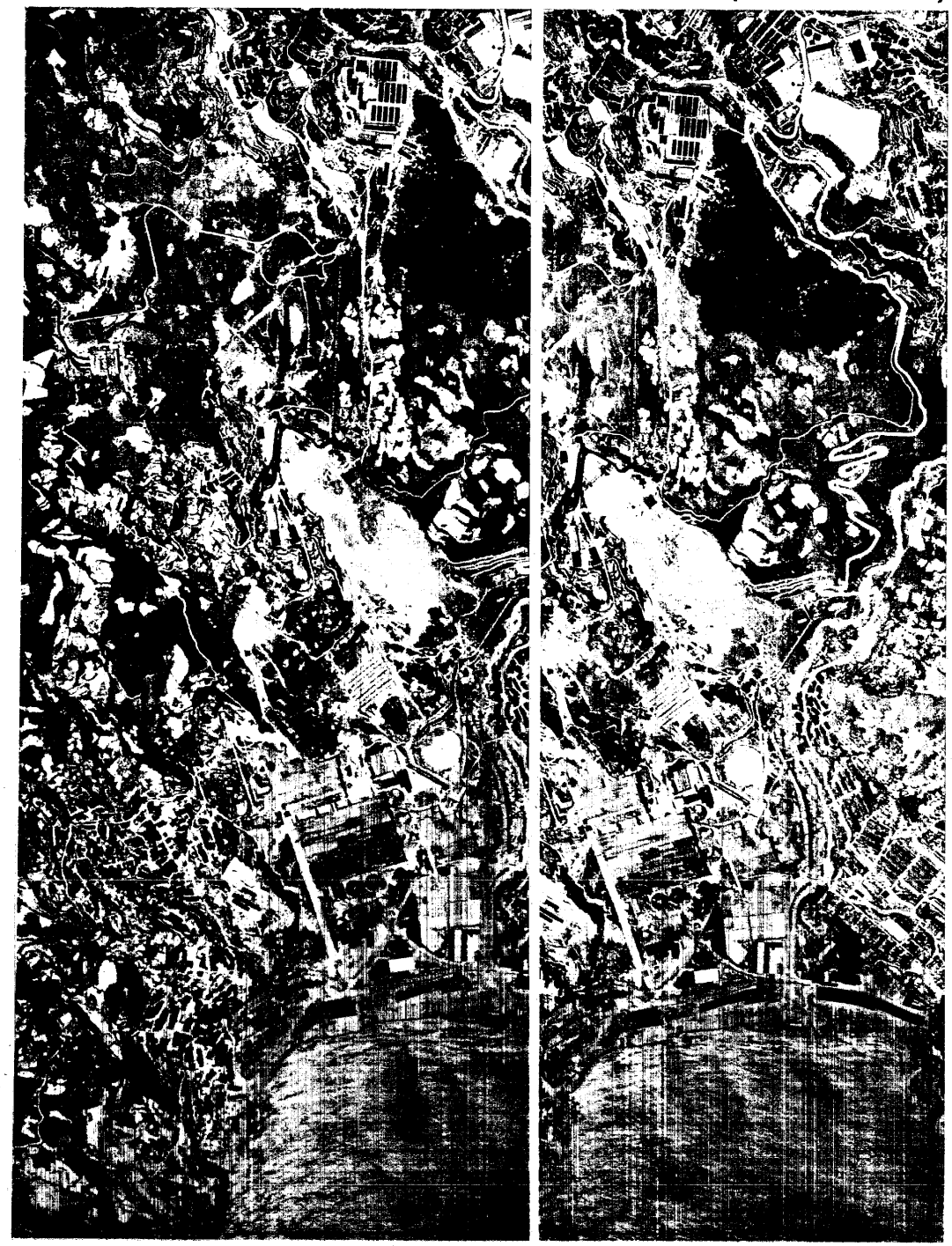
KINKASEKI, FORMOSA - CONCENTRATOR



MINING AND ORE DRESSING (STUDY PHOTOS)



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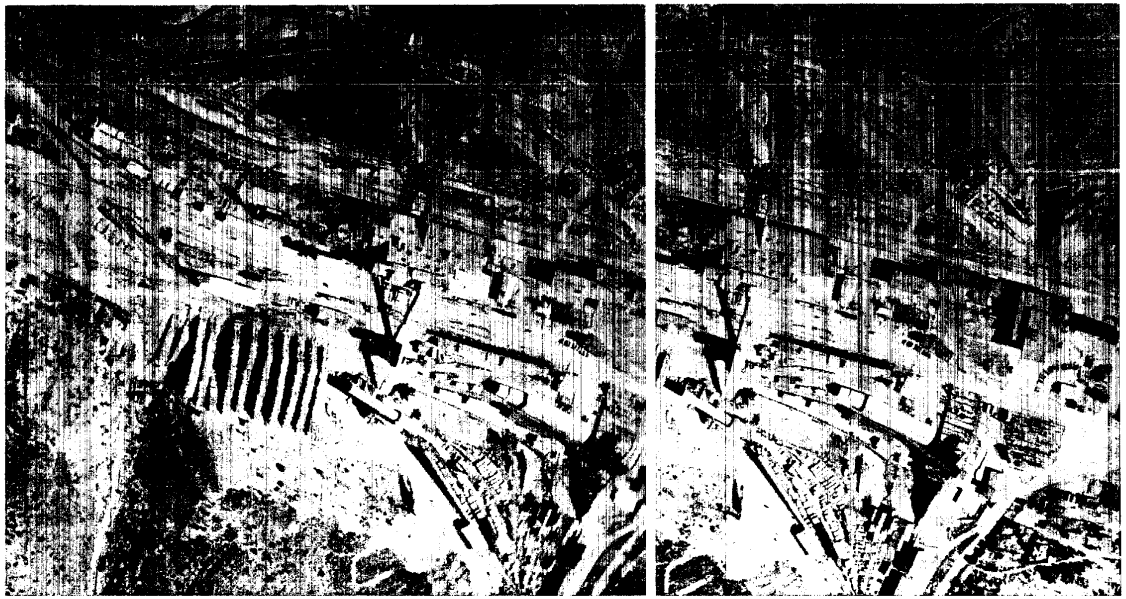
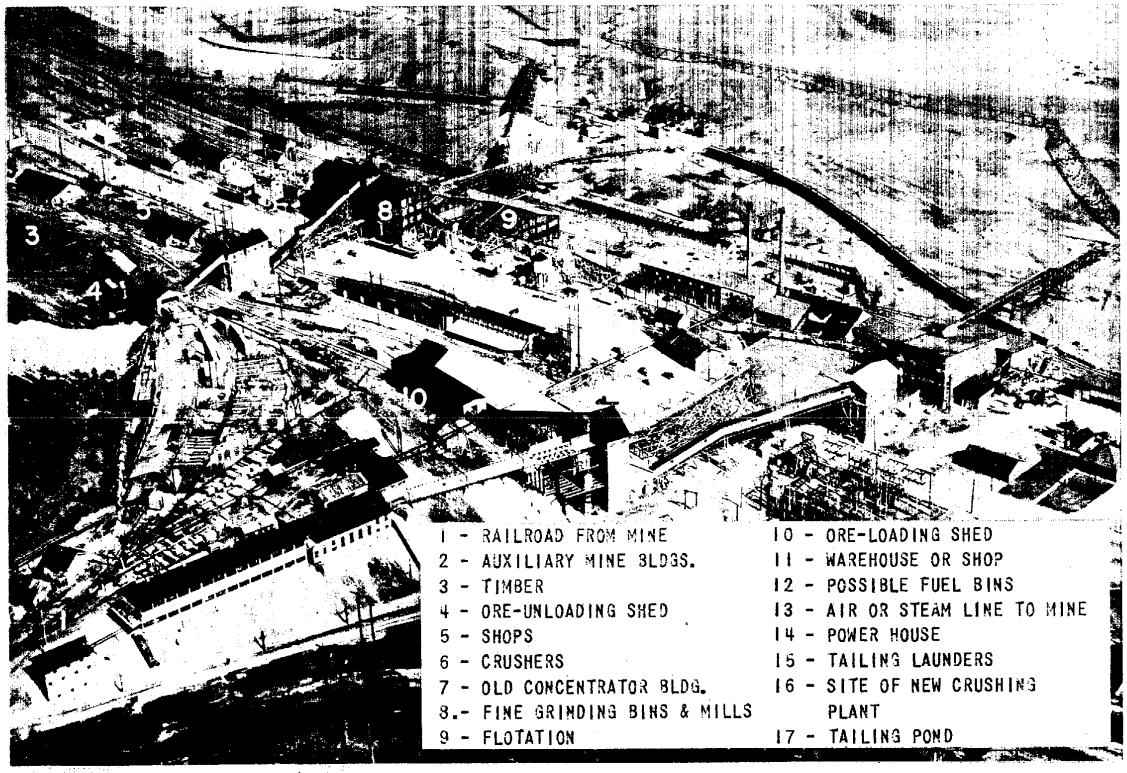
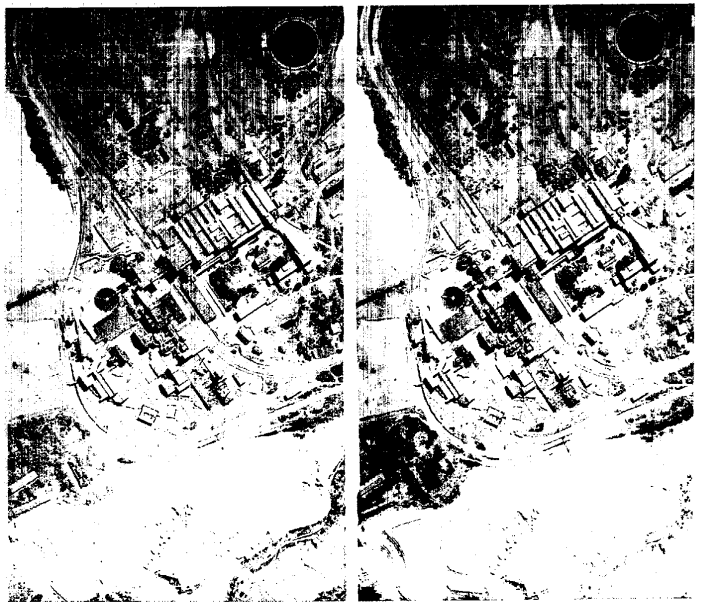
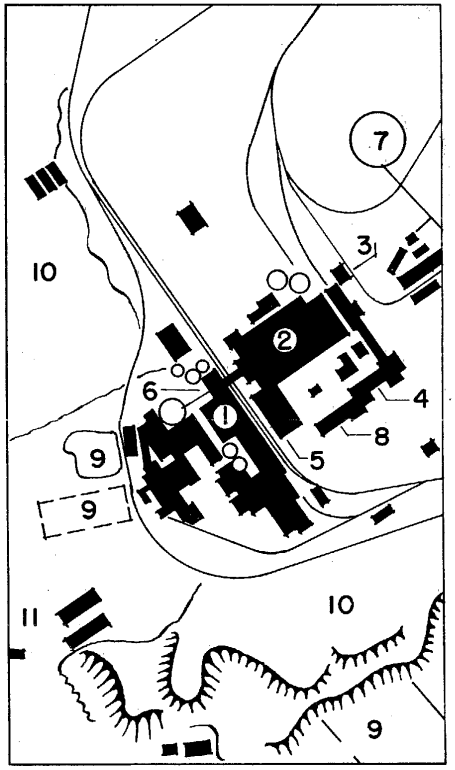


BUNKER HILL CONCENTRATOR. STEREO ABOVE, KEY BELOW





NAMTU, BURMA - CONCENTRATOR. STEREO VIEW WITH KEY



1. FLOTATION MILL.
2. GRAVITY CONCENTRATION MILL.
3. MILL ELECTRICITY SUB-STATION.
4. MILL CRUSHER HOUSE.
5. COARSE CONCENTRATES STORAGE PLATFORM.
6. 80 FT. TRACTION THICKENER.
7. MILL RESERVOIR.
8. MILL SUPERINTENDENT'S OFFICE & MILL EXPERIMENTAL OFFICE.
9. ZINC CONCENTRATES STORAGE DAMS.
10. TAILINGS DUMPS.
11. COOLIE LINES.

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VULNERABILITY OF MINES AND ORE DRESSING PLANTS

MINING

Mining installations are generally considered poor bombing objectives, (1) because output from a single mine does not usually constitute a large percentage of a nation's total production; (2) because the few vital targets at a mine are small and hard to damage without direct hits; (3) because mining equipment is standard and can be easily shifted from mine to mine; (4) because mining operations are flexible and can be adapted to all but the severest damage; and (5) because the time lag between mining operations and manufacturing operations is so great that stock piles built up in intermediate stages tend to cushion the effects of bomb damage.

If mines are selected as bombing targets, the most effective means of interfering with ore production is the damaging of primary power plants or transformers. Such damage cannot be easily repaired and as a result important equipment like hoisting machinery, air compressors, flood control pumps (at wet mines), and ventilating fans may be put out of order. The pumping system is absolutely essential to the working of a wet mine, for once pumps suspend operation, the mine will flood and begin caving. Similarly, at shaft type mines, if the delicate hoisting machinery can be seriously damaged, shaft operations will be stopped.

ORE DRESSING

Ore-dressing buildings and equipment are much larger, much more concentrated, and more vulnerable to bombing than mining installations. Therefore, because the dressing mill and the mine are nearly always located within a few miles of one another, the dressing plant represents the priority target and should be the focal point of bombing attacks. In Japan the bottleneck of metallurgical industries lies in limited supplies of ore and not in its abundant smelting and refining capacities. The destruction of dressing mills would seriously reduce the output of Japanese concentrates with a resultant effect of much greater magnitude than if similar damage were done to U.S. concentrators.

Nevertheless, the dressing mill possesses many of the same defects as a target that the mine possesses. For example, the number of dressing mills is roughly identical with the number of mines, and as a result few mills are responsible for large percentages of total national production. Also, although dressing mills tend to present a more concentrated target than mining installations, their total area, is still relatively small and would be hard to hit except at low altitudes. Other factors that would lessen the effectiveness of raids on dressing mills are (a) the heavy nature of crushing and grinding machines (b) the easily replaceable character of jigs, tables, and flotation cells, and (c) the arrangement of crushing, grinding, and concentrating equipment in parallel in such a way that a machine requiring repair can be stopped without effecting the operation of its neighbors.

KEY INSTALLATIONS AT THE DRESS NG MILL

Power House: Nearly all of the machinery at an ore-dressing plant is electrically operated; so if the power house or sub-station can be destroyed, unless other power sources are immediately available, the entire mill will cease operations. Because of the isolated location of ore dressing plants other power sources are not always immediately available, hence dressing mills may be dependent for a majority of their electricity upon a single station at the plant site.

Concentrator Building: The concentrator building is the best target at most ore-dressing plants, both because of its size in relation to other buildings and because of the more easily damaged nature of the equipment. Furthermore, the layout of a dressing mill is generally so compact that bombs aimed at the concentrator would more than likely do some damage to settling tanks, filter equipment, launders, and reagent tanks.

VULNERABILIGY OF MILLS TO FIRE

Because no hot materials are handled in ore-dressing operations, and because building contents are largely non-inflammable, the construction of mill buildings is likely to vary from place to place depending upon the prevailing type of design and upon the materials available. In Japan, although ore bins may be of reinforced concrete and walls may be masonry, dressing mills are reported (1930) to be built predominantly of wood.

ORE DRESSING AND LEACHING PLANTS COMPARED

Technically hydro-metallurgy should fall in the sections of this study that deal with extraction, but because many of the distinguishing features of ore-dressing mills and leaching plants (which form the major part of hydro-metallurgy) are similar, the general characteristics of leaching are briefly considered here.

Leaching processes are treated in detail in Section IV, because they are of major importance in the production of electrolytic zinc. Important leaching methods for copper and lead have also been developed in western countries, but in Japan such methods are probably still largely experimental. Nevertheless as early as 1930 a pilot plant for leaching of copper ores was in operation at Amagasaki; so the photo interpreter should keep the possibility of Japanese copper leaching in mind.

Briefly, ores are leached by treatment with a solvent that causes the valuable metal to go into solution leaving the valueless gangue (or tailing) unaffected. The metal in solution is subsequently precipitated out. The most effective leach solvents are sulphuric acid, sulphates, and ammonia. Water also acts as an effective leaching agent in mine tunnels as has been noted above.

Generally only oxidized ores, mixtures of oxides and sulphides, or carbonates are adaptable to leaching processes and not all of these can be exploited practically. Theoretically sulphides oxidized by roasting can also be leached, but for copper and lead ores this process usually proves to be too expensive in practice. Solutions formed with sulphuric acid and sulphate leach liquors make good electrolytes and are subjected to electrolysis in order to precipitate the metal. The metal present in solutions formed with ammonia, is usually precipitated by cementation on scrap iron. Electrolysis though more expensive, produces pure copper, while cement copper obtained from cementation is impure and must be fire refined.

In order to make the action of leach liquors effective, ores are crushed before leaching, thereby exposing a greater surface area to chemical reaction. As at the dressing mill, leaching ores are brought from the mine to the plant by railroad or conveyor and stored in primary ore bins. From these they are fed through crushers and reduced to the texture of coarse sands. Intermediate bins store the crushed ore which is subsequently classified in small settling tanks in order to separate coarse materials from slimes. Slimes are not well adapted to leaching and must be continually agitated during treatment because they tend to form an impervious layer at the bottom of leach tanks. Leach tanks are large square or rectangular vats from 60-175 feet on a side and 16-20 feet deep. They are serviced by a bridge crane that charges the crushed ore and excavates the leached tailings.

Chemical precipitation of metal from ammonia solutions and from weak electrolytes is carried on in tanks similar to those described under mine water cementation. These tanks are usually smaller than the leaching vats. Electrolytic precipitation occurs in a large rectangular

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MINING AND ORE DRESSING

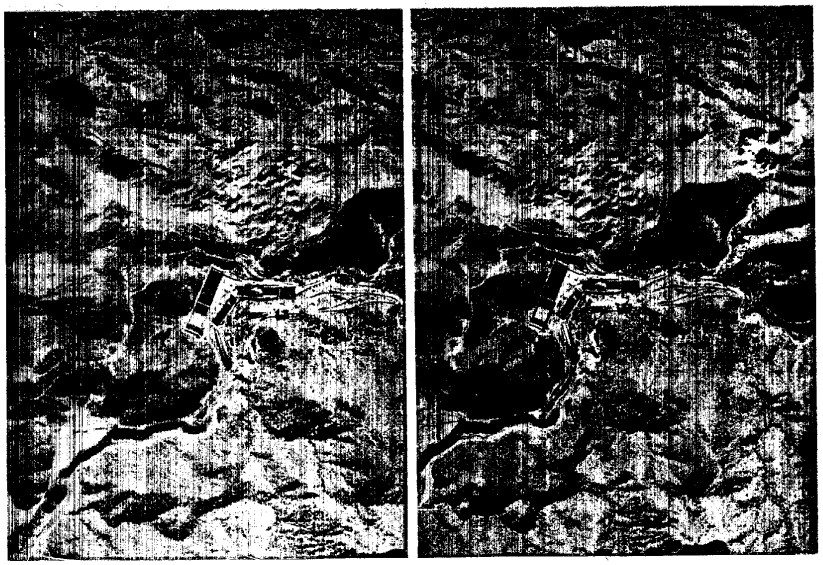
ORE DRESSING AND LEACHING PLANTS COMPARED

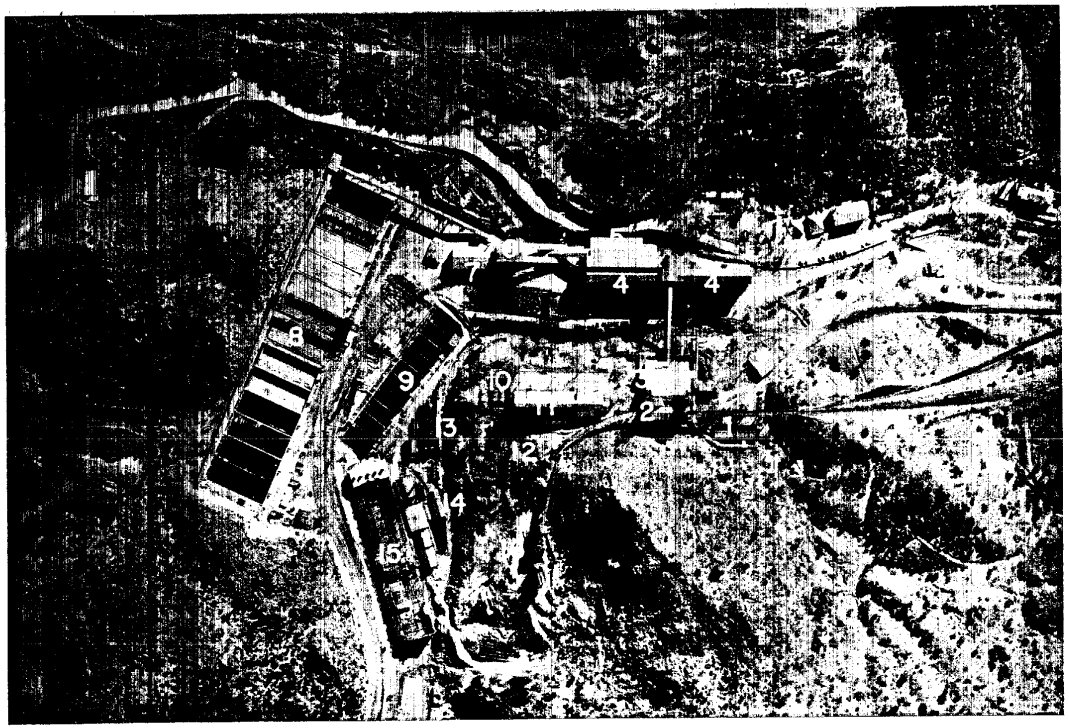
tank house much like those described in later sections on copper refining, electrolysis of zinc and the Betts process of lead refining. At some Teaching plants flotation methods are used to separate valuable elements from slimes that have first been leached and precipitated.

The photos below show a large copper leaching establishment in the United States. Similar plants in Japan would undoubtedly be much smaller.

SUMMARY OF LEACHING PLANT CHARACTERISTICS

Primary ore bins served by railroad or conveyor
Crusher building
Intermediate ore bins
A number of large exterior leaching tanks
Smaller cementation tanks and/or large rectangular tank house.
Solution storage vats or tanks, and solution purification buildings.
Large granular tailing dump
Occasional flotation mill for slimes.
Sometimes circular settling tanks.





DOMESTIC LEACHING PLANT

1. CHANGE HOUSE
2. ORE-BINS
3. CRUSHER PLANT
4. CRUSHED ORE BINS
5. SPECIAL LEACHING PLANT
6. SCREEN HOUSE
7. CLASSIFICATION PLANT
8. LEACHING TANKS
9. ACID SOLUTION TANKS
10. SPRAY POND
11. COMPRESSOR AND HOISTING PLANT
12. SUB-STATION
13. ACID TANKS
14. SOLUTION TREATMENT BUILDING
15. TANK HOUSE (UNDER REPAIR)
16. SULPHURIC ACID PLANT
17. R.R. TO TAILING DUMP

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SECTION 2

COPPER METALLURGY

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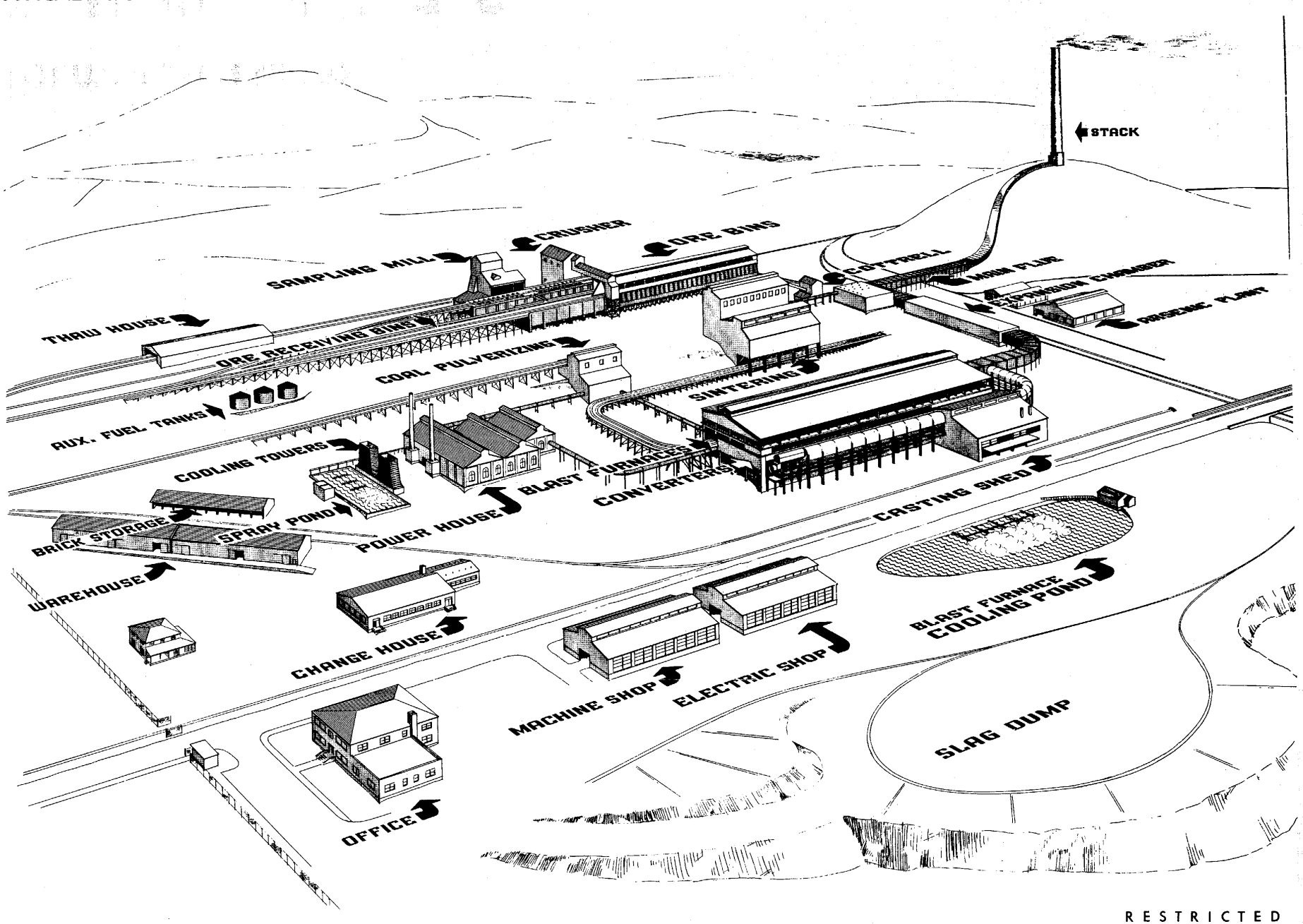
TYPICAL COPPER SMELTER



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INTRODUCTION

Copper metallurgical operations divide naturally into *extraction processes* which are carried on at the smelter or leaching plant, and *refining processes* which are normally carried on at the refinery. In extraction processes ores and concentrates are reduced to 96-99% pure copper by either pyro-metallurgical or hydro-metallurgical methods. In refining processes the crude copper gained from extraction is purified by pyro-metallurgy, by electrolysis or, as is most often the case, by a combination of both. The choice of extraction and refining methods is dictated in each instance by the chemical composition and physical characteristics of the ores and concentrates treated.

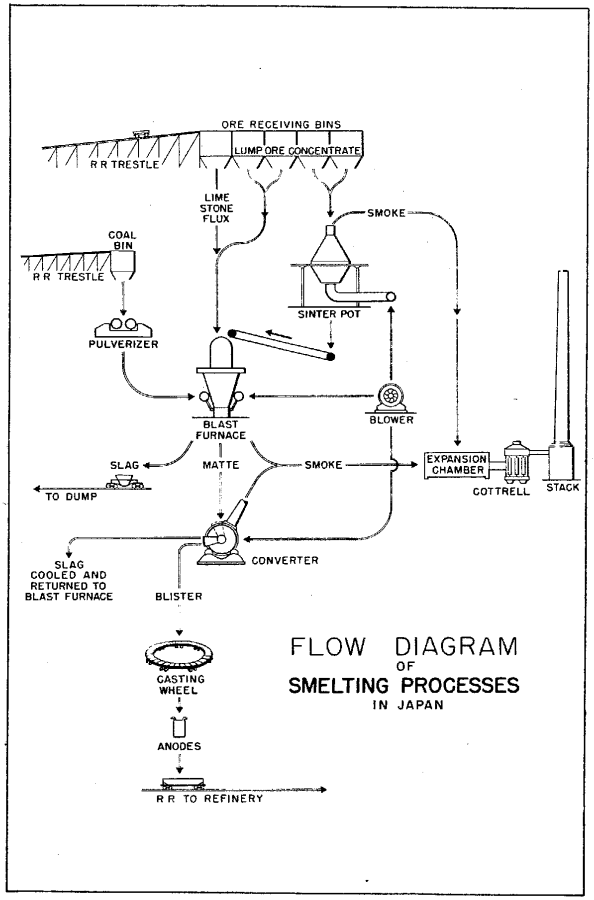
Because copper ores mined in Japan are nearly all sulphides and because smelting is the only important extraction process used, this study deals only with the smelting of sulphides.

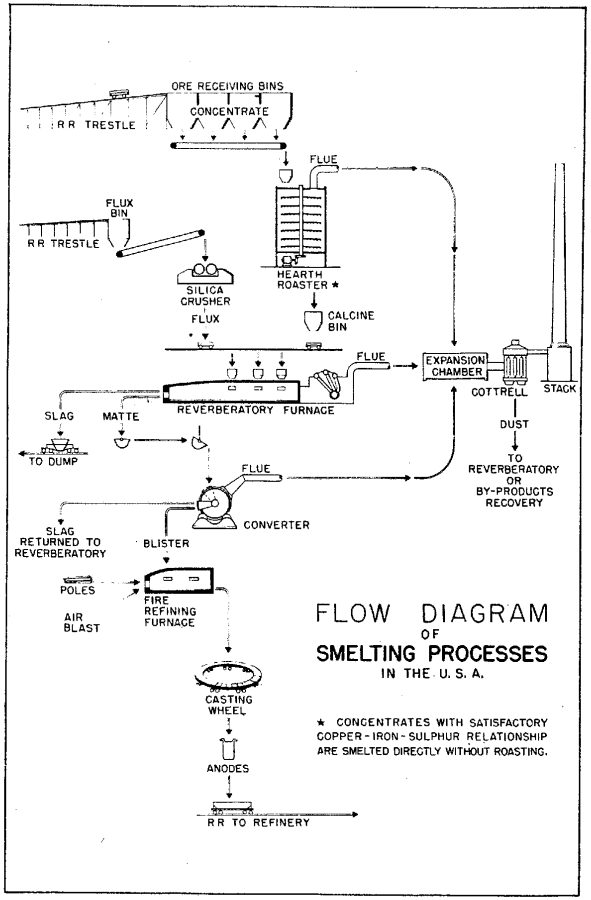
MATTE SMELTING OF SULFIDE ORES

The ultimate objective of any method of extracting copper from its ores is to obtain the primary metal as economically as possible in a highly purified state, and to reject the accompanying materials in such form that valuable by-products, if present, can be recovered. In the smelting of copper sulphides the aim is to separate copper from the iron, sulphur, and gangue materials that make up the bulk of the ore. This separation, known technically as "matte-smelting", generally involves three distinct operations called roasting, smelting, and converting.

(1) *Roasting* in the United States is designed to adjust the sulphur-copper-iron ratio of the ore, thereby forming a proper relationship for economical treatment in the subsequent stages of smelting and converting. If this relationship is satisfactory without roasting, ores and concentrates are sometimes smelted raw.

Roasting in Japan, however, is combined with smelting and takes place in the smelting furnace. Prior to smelting, finely divided furnace charges are commonly subjected to a special type of roasting called "sintering". Sintering is designed to agglomerate the minute concentrate particles of the charge in order to permit efficient smelting. The principal product of either roasting or sintering is a hot calcine. Secondary products, sulphur, arsenic, antimony, and bismuth are volatized during the process and are passed off as fumes or gases.





(2) *Smelting's* main function is the removal of gangue as slag and the fusing of the copper, iron, and sulphur into a liquid matte. Matte by definition is any sulphide that has been prepared artificially by fusion. In addition to copper, iron, and sulphur it contains small amounts of other metals such as gold, silver, lead, zinc, nickel, arsenic, and bismuth.

(3) *Converting* separates the copper in the matte from the iron and sulphur by oxidation. Sulfur is driven off as SO_2 gas and the iron forms a slag with the furnace fluxes.* The crude or "blister" copper which is the product of converting contains from 1 - 4% impurities. These are subsequently removed by fire refining and/or electrolysis.

The principles of roasting, smelting, and converting are the same for copper metallurgical operations all over the world, but the details of equipment and practice employed by each nation vary with the extent and type of the ores exploited. As the most important world producer of copper, the United States possesses the largest and the most up-to-date production facilities. Japan, on the other hand, although the second largest world producer during World War I, suffers from limited supplies of copper ore and has not been able to keep pace with the United States. The smaller scale production and the great variety of ores mined has in fact tended to force the Japanese to employ somewhat different techniques of matte-smelting from those used by the U. S. The

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essential steps followed during roasting, smelting, and converting operations in the two countries are shown in the flow diagrams.

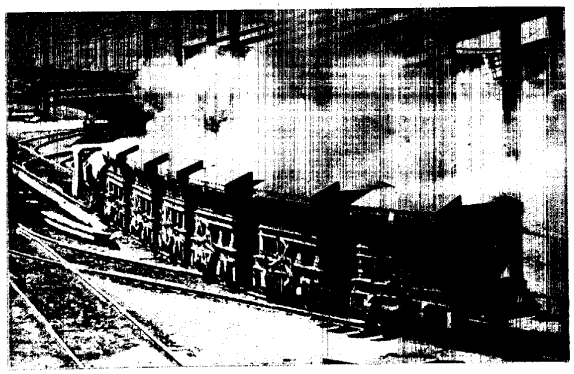
ROASTING

The variance in roasting practice between the United States and Japan is explained by the fact that Japanese smelting is carried on predominantly in blast furnaces, while U.S. smelting is done in reverberatories. In the first instance the choice of blast or reverberatory furnaces is dictated by the nature of the ores and concentrates available for smelting. Thus, blast furnaces are best adapted to the smelting of coarse materials and reverberatory furnaces are best suited to the smelting of fine concentrates. When finely divided materials are treated in blast furnaces, a large percentage of the grains are lost to the atmosphere in the uprising air blast, and the material that stays in the furnace tends to pack into incompletely smelted masses.

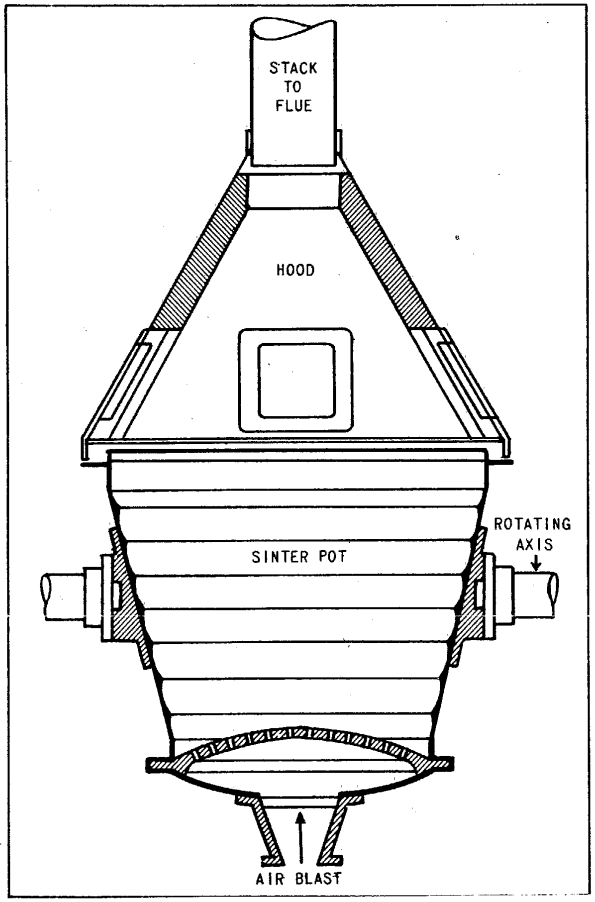
The coarse pyritic ores that form a substantial part of the Japanese blast furnace charge are high in sulphur content and have therefore made it possible for the Japs to employ a process called "partial pyritic smelting". The success of this process is based partly upon the fact that the heat generated from the exothermic reaction of burning sulphur greatly reduces required amounts of fuel. In order to utilize this sulphur content completely, blast furnace charges are not subjected to a preliminary roast as are reverberatory charges. Instead both roasting and smelting stages are carried on as one in the blast furnace.

With the increased use of concentration methods in Japan, furnace charges have become more and more finely divided, and as a result at Japanese smelters which employ blast furnaces alone, special treatment of concentrates has become necessary in order to form a chargeable solid. This conversion of fines to solids is accomplished by either sintering or briquetting. Sintering processes subject the fines to various methods of blast roasting which eliminate some sulphur but which primarily agglomerate the concentrate into porous lumps that are ideally suited to blast furnace operations. The calcine agglomerate obtained from sintering is moved directly to blast furnaces in "hot-calcine" cars in order to economize on heat. Briquetting treats the concentrates without heating, merely by stamping them into solid cakes on a number of small presses placed in parallel.

"HOT-CALCINE" CARS

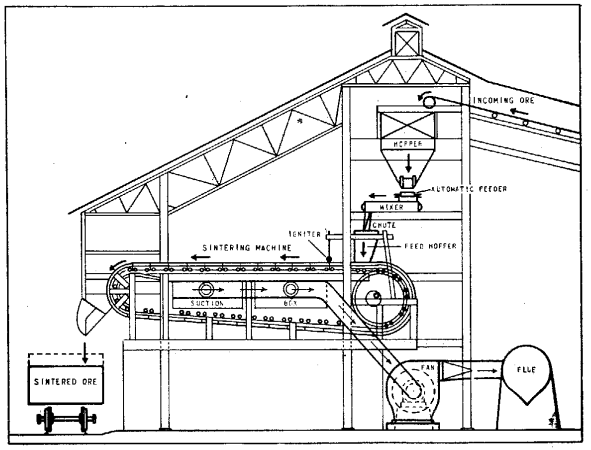


Sintering Equipment: Sintering equipment used in Japan includes the sinter pot, the Greenwalt pan, and the Dwight-Lloyd belt. The sinter pot is a cast iron container that measures from 8-10 feet in diameter and from 4-6 feet in depth. Operation of the pot begins with the kindling of a small wood fire on the bottom and is maintained by burning sulphur in the charge. An air blast emitted at the pot bottom assists the reaction.

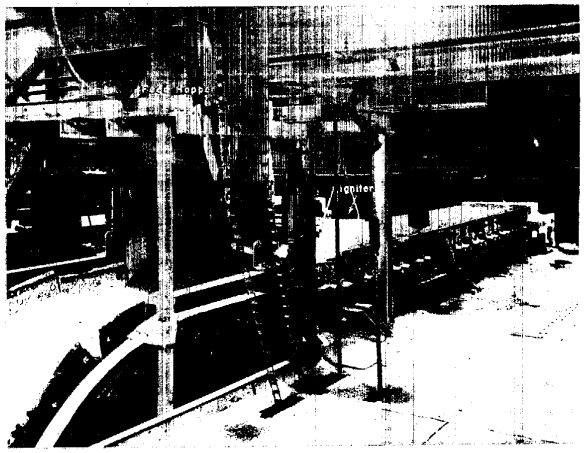


The Greenwalt pan is a rectangular cast iron or steel pan that measures roughly 8 x 16 feet with a depth of approximately one foot. It operates much the same as the sinter pot.

The Dwight-Lloyd sintering machine consists of a structural steel framework that supports an enclosed endless belt fitted with small grate bottomed pallets.



ABOVE: SECTION THROUGH SINTERING BUILDING
BELOW: DWIGHT-LLOYD BELT IN OPERATION



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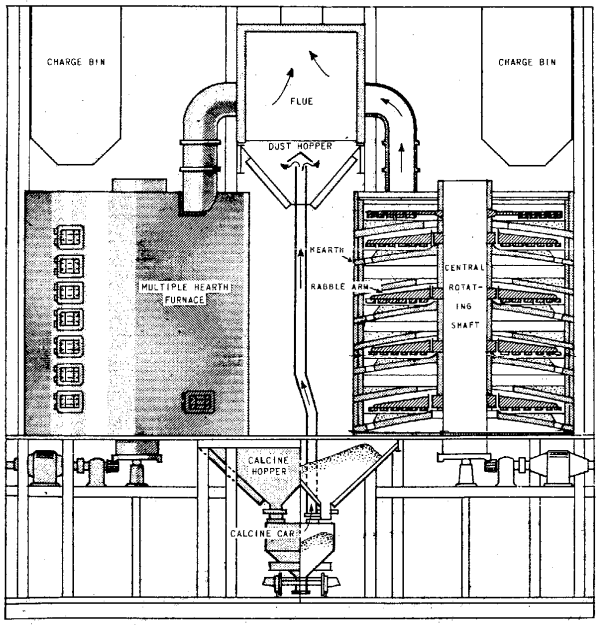
The concentrate charge is fed to the pallets from a hopper placed above the machine, and is ignited by a hooded burner. The belt then carries its pallets, spread with ignited concentrates, across a suction box where air is drawn through the burning charge resulting in the formation of a sinter cake. If the sulphur content in the charge isn't high enough to support combustion alone, coke is mixed with the concentrate feed. If the sulphur content in the charge is so high that excessive exothermic heat causes concentrate particles to fuse, the material flow is rearranged to permit two short passes through the same machine or through different machines placed in parallel.

In fact, in all three of these sintering processes a number of units are placed in parallel and are served by a single conveyor system. Because of their limited capacity sinter pots usually number around a dozen. Greenwalt pans, although of slightly larger capacity, are also used in relatively large numbers, while Dwight-Lloyd machines ordinarily number around two or three, inasmuch as they have a much greater capacity.

Hearth Roasting: Some attention should be devoted at this point to the practice of multiple-hearth roasting because it is definitely known that a few Japanese smelters employ hearth roasting in place of sintering. For example, it was reported in 1930 that one Japanese smelter (Naoshima) treated all of its raw materials in hearth roasters and then smelted them in reverberatory furnaces. Further reports claimed two other plants used roasters and reverberatories for their flotation concentrates. Some Japanese smelters may still use the practice of hearth roasting as a part of the blast furnace reduction-smelting process that prevailed in Japan before the introduction of partial pyritic smelting.

Standard multiple-hearth furnaces like the ones illustrated consist of a number of refractory brick hearths enclosed in a tall steel cylinder. Concentrates are fed to the furnace from a hopper at the top and then raked or rabbled across each of the successive roasting hearths below. Rabbling is accomplished for each hearth by a rake that revolves on a rotating steel column. In addition to hot calcine, roasting produces volatile products like arsenic, antimony and sulphur which are drawn off through gas outlets that connect with a flue leading to the main smelter stack. Heat is supplied to alternate hearths by burners set in the side wall of the furnace.

MULTIPLE HEARTH ROASTERS



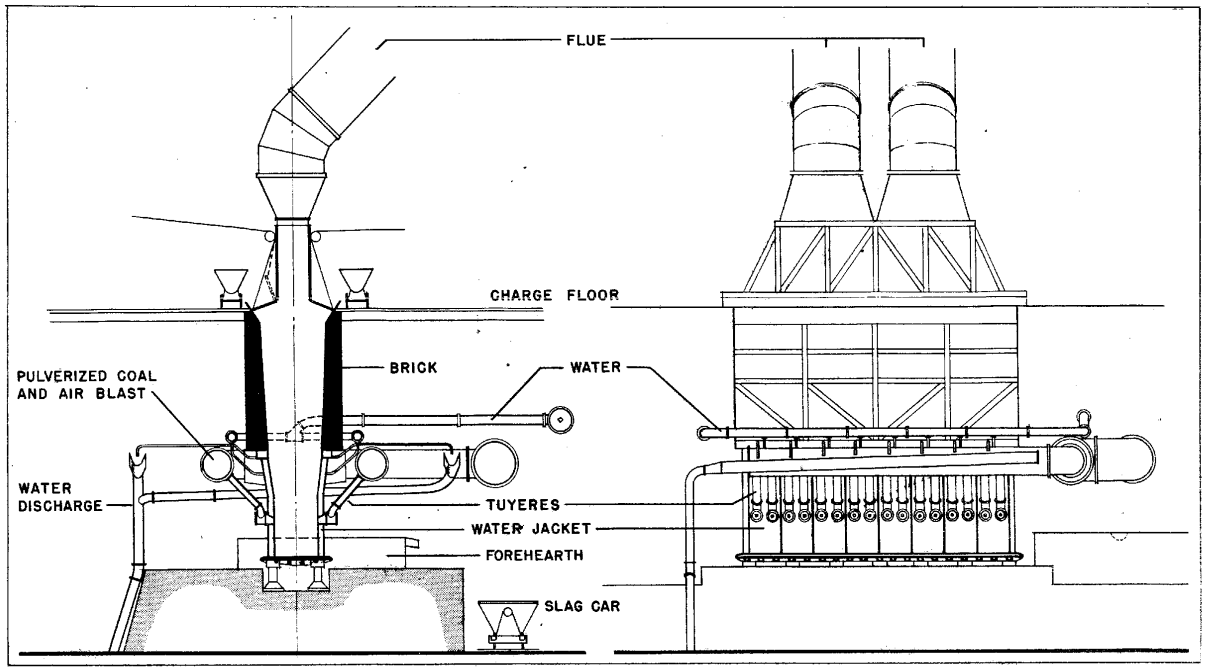
SMELTING

The "smelting" stage is essentially a melting operation in which copper, sulphur, and iron from the furnace charge fuse into liquid "matte". Other products yielded in addition to matte are slag and flue gases.

Blast Furnace Operations: The operation of a copper blast furnace is similar to that of an iron blast furnace in principle, but quite different in equipment and practices employed. For example, copper blast furnaces stand about 20 - 30 feet in elevation and are housed, while iron blast furnaces sometimes stand 150' in elevation and are uncovered. No hot stoves are needed as in the production of iron, because the air blast for the copper furnace is generally introduced cold. The iron furnace is circular in construction while the copper furnace is long, narrow, and tapered on the sides roughly in the form of a rectangular funnel. Copper furnaces measure between 3 and 4 feet wide and vary in length from 25 - 90 feet. At Japanese smelters, furnaces average 25 feet in length.

Like the iron blast furnace, the copper furnace is encircled by a large bustle pipe containing compressed air which is fed into the charge column through tuyeres

SECTION AND ELEVATION OF BLAST FURNACE



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or nozzles inserted in the side walls. At most smelters compressed air blowing engines are located at the power house and are connected with the furnace building by a large conductor pipe. If the power unit is only a substation, however, air compressors are likely to be set up in a separate building with steam boilers of its own. The base of the copper furnace is constructed with steel water jackets and the top is built with refractory brick. This brick top is usually enclosed, connected on one side to a flue system for the removal of waste gases and equipped on the opposite side with charging doors.

Charging is a continuous operation that may be accomplished by dumping directly from calcine cars or skip hoists. The actual charge consists of varying proportions of high grade ores, sintered concentrates, fluxes, and reverts of dust and converter slag. The charge sinks slowly in the column as it becomes heated in the lower part of the blast furnace. Therefore, additional material must be regularly supplied through the charge doors.

In most blast furnace operations coke or charcoal is added to the charge as fuel, but in Japan fuel is almost exclusively pulverized coal blown into the furnaces through tuyeres. The coal is pulverized in mills similar to those employed for fine grinding at the concentrator. The coal particles are normally blown from the crusher building to the blast furnaces through large compressor pipes.

Matte and slag continuously flow from the furnaces into a large circular or oval receptacle called a settler or forehearth. The matte is tapped as needed from the bottom of the settler into ladles which are moved by overhead conveyor to the converter furnace. Slag overflows continuously from the forehearth into "hot-metal" rail cars that deposit their load in an adjacent dump. Occasionally smelter slag in Japan is used as ballast for railroad tracks, and in a few instances it has been used to manufacture "asphalt" paving blocks.

Japanese smelters contain an average of 4 or 5 blast furnaces, at least a few of which are alternates that can be placed in operation when other furnaces are closed down for repairs. Furnaces are generally arranged in a row down the center of the smelter building, while the building contains three floors: the feed floor, the furnace floor, and the slag or matte floor. The details of the feed floor vary with the manner of delivering charges to the furnace. The distance between the feed and the furnace floors is governed by the height of the furnace, whereas, the slag or matte floor has to be a sufficient distance (roughly 10 feet) below the furnace floor to admit slag cars with a capacity of 5 to 15 tons.

Reverberatory Furnace Operations: The reverberatory furnace is a long low rectangular silica brick structure with an arched roof. This arched construction limits furnace width to about 30', but length may vary from 90 - 140 feet depending upon the needs of the smelter. Modern matte reverberatories average just over 100' long and about 25' high. A steel framework holds the brick walls and roof together under tensions set up by the

SIDE VIEW OF REVERBERATORY FURNACE

intense smelting heat within.

Reverberatories are charged through openings in the roof or at the top of the side walls, and heat is supplied by means of burners that are inserted in one end wall. Charges consist of concentrates (roasted or unroasted), converter slag returned from the final converting operation for retreatment, other reverts in the form of flue dust, refinery slag, and suitable fluxes which are dictated by the impurities in the rest of the charge. Fuels which will give a long burner flame are generally used. These may be coal, pitch, fuel oil, or gas. When coal or pitch is used it must first be pulverized.

Tap holes for matte and slag, and flues for furnace gases are generally located at the opposite end of the furnace from fuel burners. Matte is tapped into ladles; slag is drawn off into "hot-metal" rail cars, and flue gases are carried through a waste heat boiler and dust collection system the details of which are described below.

Because the demands for copper matte at the converter are frequent, the reverberatory operation is continuous, i.e., some liquid matte is always available in the collecting pool at the tapping end of the furnace. In order to insure this continuity of operations furnace charge and fuel needs must be regularly supplied.

CONVERTING

Converting operations can be generally divided into (1) a slag forming stage and (2) a blister forming stage. In stage (1) iron is slagged off and some sulphur is volatilized as SO_2. In stage (2) the remainder of the sulphur is eliminated and blister copper is formed.

No fuel is needed to keep the furnace hot between stages because matte from the smelting furnace is charged white hot to the converter and because the reactions are exothermic.

In actual practice, stage (1) is usually repeated several times and the resultant slag skimmed off until enough cuprous sulphide has been accumulated in the converter to begin the second stage of blowing for blister copper. Slags are recharged into the smelting furnace.

When stage (2) has been completed and the blister is entirely formed, the resultant metallic copper is treated in one of several ways. At Japanese smelters, blister is commonly cast directly into anodes for treatment in the tanks of electrolytic refineries. Some U.S. smelters move blister in hot-metal ladles from converters to refining furnaces and fire refine directly at the smelter; others cast blister into cakes that can be shipped to refinery furnaces at the electrolytic refinery. Details of refining and casting are treated in the next section.

Upright or Great Falls Type Converter: Converters used in modern copper metallurgy are either "upright"

UPRIGHT CONVERTER AISLE

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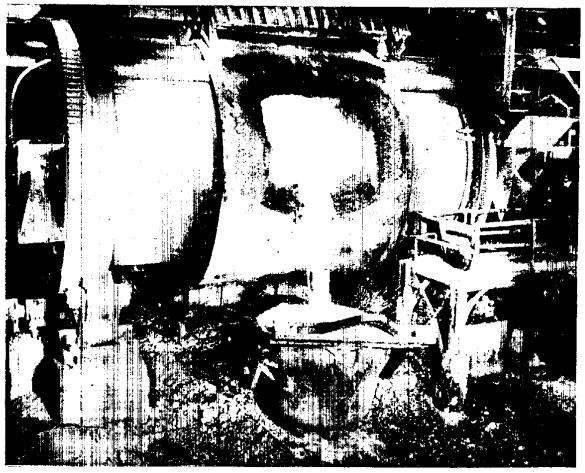
or "horizontal". The Great Falls type which closely resembles the Bessemer steel converter is the standard "upright" converting equipment in use today. It consists of a short cylindrical steel section from 12 - 20 feet in diameter surmounted by a tapering hood. The lower section is mounted on trunnions to permit turning for charging matte and pouring slag and blister. During blowing operations the hood covers the lower shell and conducts SO_2 gas through a flue that connects with the main smelter stack.

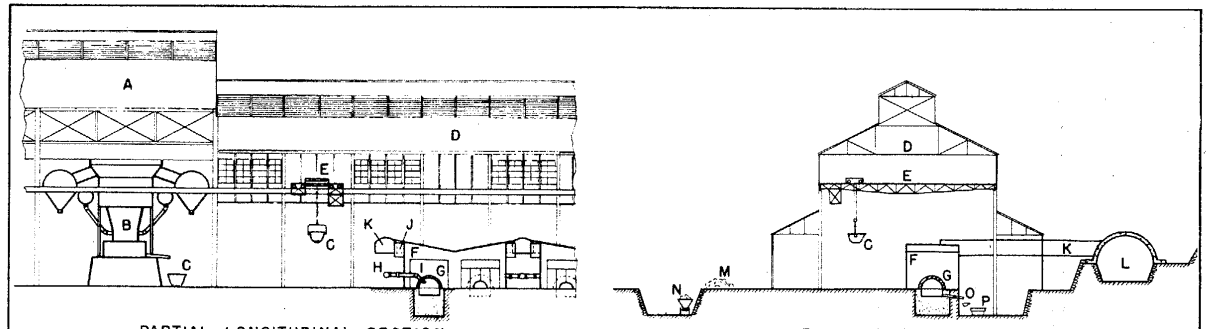
Horizontal or Barrel Converter: The horizontal or barrel converter is more widely used than the Great Falls converter and is best represented by the modern Pierce - Smith product illustrated. Horizontal converters possess the same general characteristics as the G.F. type, i.e., a horizontal turning axis and a hood for collecting SO_2 gas.



TAPPING BLISTER COPPER FROM A PIERCE-SMITH CONVERTER

Mabuki Hearth Operations: Most of the largest Japanese smelters (about five) are now equipped with either Great Falls or barrel converters, but the important Sagonoseki smelter and most of the smaller smelters employ in place of converters a strictly Japanese type furnace known as the mabuki hearth. In principle the mabuki operates much the same as a converter and is used side by side with converters at many Japanese smelters.

Mabuki hearths consist of a pit dug in the ground, lined with refractory materials, and covered by a hemispherical roof of clay or siliceous ore. At one end of the hood a door provides access for charging and slagging and at the other the hood connects with a flue for the disposal of waste gases. Air and fuel are blown into the hearth through a single tuyere set in the side of the hood. Matte from the blast furnace is charged into the hearth by ladles, and slag is raked off into wheel barrows.



PARTIAL LONGITUDINAL SECTION

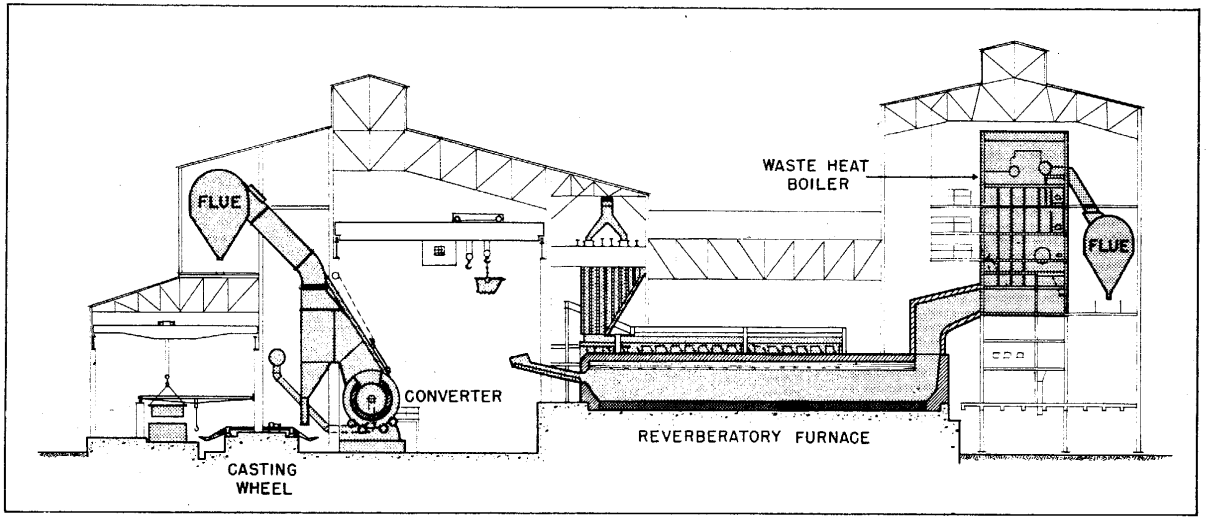
TRANSVERSE SECTION

(A) BLAST FURNACE BUILDING· (B) BLAST FURNACE· (C) MATTE LADLE· (D) "MABUKI" FURNACE BUILDING· (E) TRAVELING CRANE· (F) HOOD OF THE MABUKI FURNACE· (G) MABUKI FURNACE· (H) BLAST PIPE· (I) TUYERE· (J) OIL TANK· (K) BRANCH FLUE· (L) MAIN FLUE· (M) MABUKI SLAG· (N) SLAG CAR· (O) TAPPING HOLE· (P) ANODE MOULD

SMELTER EMPLOYING BLAST FURNACES AND MAKUBI HEARTHS

The converters are installed in the smelter building along what is termed the converter aisle. On one side of the aisle converters are arranged in a row; on the other, stand the blast furnace or tapping ends of reverberatory furnaces. With this arrangement a single overhead crane can service both smelting and converting furnaces with hot metal ladles. At some smelters converting furnaces (especially mabukis) and smelting furnaces may be arranged all in one row with the blast furnaces at one end and the servicing crane running the full length of the row along one side.

SECTION THROUGH AMERICAN REVERBERATORY SMELTING BUILDING



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TREATMENT OF FURNACE GASES AND DUST

All of the pyro-metallurgical equipment used at copper smelters, i.e., roasters, sintering machines, blast furnaces, reverberatories and converters, expel a considerable amount of waste gases, dust, and fume during operations. Strictly speaking gases refer to material which carries no solid or liquid matter in suspension. Dust includes anything in the furnace charge fine enough to be carried in smoke, and fume refers to material volatilized in the furnace and later condensed as it cools. SO_2 is the only important waste gas produced at copper smelters. Dust can consist of any material depending upon which constituent of the charge is finely divided. Fume occurs as water vapor, as droplets of sulphuric acid and sulphates, and as oxides of arsenic, antimony, lead, and zinc.

Because SO_2 gas is harmful to vegetation and formerly did considerable damage to farm land surrounding copper smelters, all smelters today have tall stacks that liberate gases to the upper atmosphere where they are diffused before reaching the ground. In fact, the tallest stacks in the world are usually found at copper smelters. At some smelters all of the different types of furnaces are connected by flues with a single tall stack; at others, roasters may connect with one stack, smelting furnaces with another and converters with a third. As will be shown in Section V, some smelters use their SO_2 gas for the manufacture of sulphuric acid.

Recovery of Dust and Fume: The methods employed at copper smelters for removing suspended material from smokes are: (1) collection of dust beneath flues, expansion chambers, etc.; (2) filtration through cloth bags in "bag houses"; and (3) electrostatic precipitation in Cottrell treaters.

The principle involved in the collection of dust and fume in expansion chambers, flues etc. is simply that as smoke is cooled by radiation and by expansion in large chambers, its velocity and carrying power diminish. Cooling condenses the fume, and the action of gravity precipitates both fume and dust upon the chamber bottom where they can be removed periodically through hopper doors. Actually only the larger particles settle out in this way; finer particles remain in the smoke stream where they must be removed by other methods.

One of these other methods is the filtration of smoke and gases through cloth bags in a bag house. However, because most copper smelter smokes are acid in character and eat away the fabric of the bags, bag houses are not widely used at copper smelters and will be described in more detail under lead and zinc metallurgy.

In the place of bag houses most smelters employ Cottrell treaters. The Cottrell process utilizes the fact that if an electrostatic charge can be placed upon dust particles, they can be attracted to an electrode carrying the opposite charge. Positive or collecting electrodes are usually pipes or plates and negative electrodes are either wires or chains. At regular intervals the deposit that accumulates at the positive electrode is discharged by tapping the pipes or plates with automatic hammers. Some smelters emit non-conducting smokes that must be conditioned by passing through a water spray before they can be successfully treated, but once conditioned practically any type of suspended material can be removed from the gas stream by Cottrell treaters, sometimes as much as 97%. Although some dusts recovered by Cottrells go to roasters and converters and others receive special treatment, the majority are charged back into the smelting circuit to reverberatory or (after briquetting) to blast furnaces.

Arsenic Recovery: The principal by-product from smelter fume is "white arsenic". In fact practically all of the world's supply of arsenic is a by-product of copper and lead smelting. When the arsenic is present in the smelter feed in any quantity, it tends to accumulate along the flue system as precipitated fume originally volatilized from both roasting and smelting furnaces. Treatment of arsenic bearing dusts begins with a roasting operation in a multiple hearth furnace. Gases thus released are condensed as crude arsenic, and the residue is returned to the smelting circuit. The condensed crude arsenic is further heated in a small reverberatory furnace and then recondensed in a maze of brick chambers (arsenic kitchens) as commercial "white arsenic".

Waste Heat Recovery: When the smelting operation at a copper smelter is carried on in reverberatory furnaces, a lot of the heat generated by fuel burners is expelled with the waste gases. In order to recover as much of this waste heat as possible gases are run through a steam boiler before being treated for dust recovery. The steam thus generated is used principally for power in conjunction with outside boilers. Waste heat boilers are located slightly above and behind the furnace they serve. As furnace gases strike the boiler tubes, in addition to losing their sensible heat, they deposit a certain amount of smoke dust. Hence at regular intervals boiler tubes must be cleaned and the recovered dust returned to the smelting circuit.

DISTINGUISHING FEATURES OF SMELTERS

Copper smelters are generally distinguished by tall 300-600' stacks which eliminate noxious furnace gases to the atmosphere. When smelters are in operation a cloud of dense white smoke issues constantly from these stacks. Two other easily noted features of copper smelters are the sprawling black slag dumps that cover a large portion of adjacent terrain and the wide winding flues that connect smelting furnaces, roasters, and converters with their stacks. Ore bins or bedding buildings for storing and mixing furnace charges, sameling mills and crusher plants, tall, often narrow roasting or sintering structures, a relatively large smelting building, and the usual auxiliary buildings complete the overall picture of the copper smelter.

DETAIL OF SMELTER CHARACTERISTICS

Ore Bins & Bedding Buildings

(1) Used to store and mix raw materials (ores, concentrates, and fluxes) prior to charging smelting furnaces.
(2) Raw materials dumped initially from rail cars into receiving bins built beneath tracks.
(3) Concentrates plus crushed ores and fluxes fed from receiving bins to silo type ore bins or to large rectangular bedding building.
(4) Storage facilities often include outdoor ore piles.

Thaw House

(1) Squat simply constructed building located near rail entrance to plant; not usually present in hot climates.
(2) Spur enters building at one end so ore cars can be taken inside to thaw contents with steam.

Crusher Plant

(1) Relatively tall building with irregular roof
(2) Used to crush raw ores and fluxes received in bulk form
(3) Usually closely associated with ore bins or bedding building but may be some distance away and serviced by conveyor.
(4) If separate from bedding system and used for fluxes alone may possess own ore bin and connect with smelter building by conveyor.
(5) Silica quarry may be located adjacent to smelter with overhead tram or rail connection to crusher.

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COPPER METALLURGY

DISTINGUISHING FEATURES OF SMELTERS

Sampling Mill

(1) Similar in appearance and closely associated with crusher plant.

(2) Used to test and crush ores and fluxes.

Sinter Building

(1) Medium sized rectangular structure; sometimes one of tallest smelter buildings to permit charging of concentrates at top and removal of calcine at bottom.

(2) Roof may be distinguished by tower-like elevator section that services feed bins.

(3) Connected by flue with stack, by narrow gauge rail with smelting furnaces, and by conveyor with concentrate storage.

Roaster Building (where hearth-roasting is substituted for sintering)

(1) Universally tall rectangular structure - ranks with ore bins and smelter building as one of largest units at the smelter.

(2) Like sinter building, distinguished by connecting flue, railroad, and conveyor.

Smelter Building (Blast Furnace)

(1) Long, high, gabled, rectangular structure - the largest at the smelter; size varies with number of blast furnaces, converters, and casting machines housed within - averages about 370' x 100'.

(2) Large winding flues lead from blast furnace and converter sections to stack or stacks.

(3) Narrow gauge tracks lead from base of blast furnace section to slag dump.

(4) Air pipes feed to blast furnaces and converters from air compressor building or power house.

(5) Small casting shed serviced by exporting railroad often attached to converter section. When casting takes place at end of main building, only exporting rail tracks are visible.

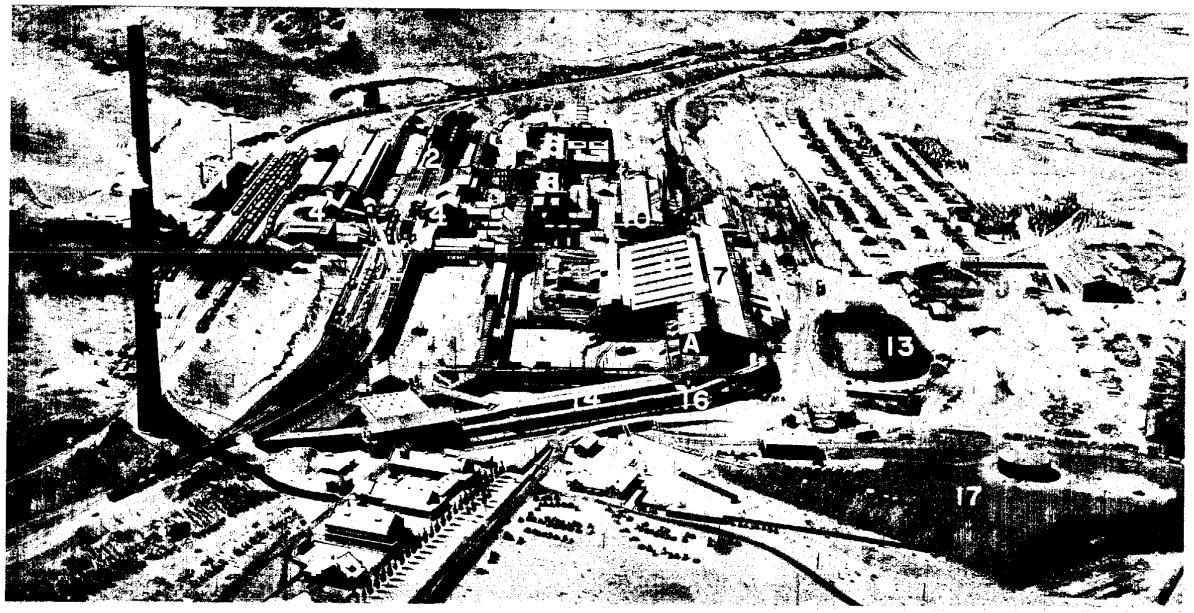
(6) Some smelters possess narrow gauge calcine charge tracks that enter building on trestle - level with feed floor. Others feed furnaces from charge bins serviced by conveyor at top of building.

(7) Pipe for powdered coal sometimes apparent leading from pulverizer to blast furnaces.

(8) Cooling pond or towers for water from blast furnace water jackets located near building.

(9) Smoke and dust produced during blast furnace charging operations often visible above building.

1.	THAW HOUSE	6.	HEARTH ROASTER BUILDINGS	10.	POWER HOUSE	15.	COTTRELL TREATER
2.	ORE RECEIVING BINS	7.	CONVERTER BUILDING	11.	MACHINE SHOPS	16.	FLUE
3.	ORE BINS	8.	REVERBERATORY SECTION	12.	COMPRESSED AIR PIPE	17.	OLD SLAG DUMP
4.	SAMPLING MILLS	9.	WASTE HEAT BOILER SECTION	13.	COOLING PONDS	18.	RAW MATERIALS
5.	CRUSHER	9A.	BLAST FURNACE SECTION	14.	EXPANSION CHAMBER		



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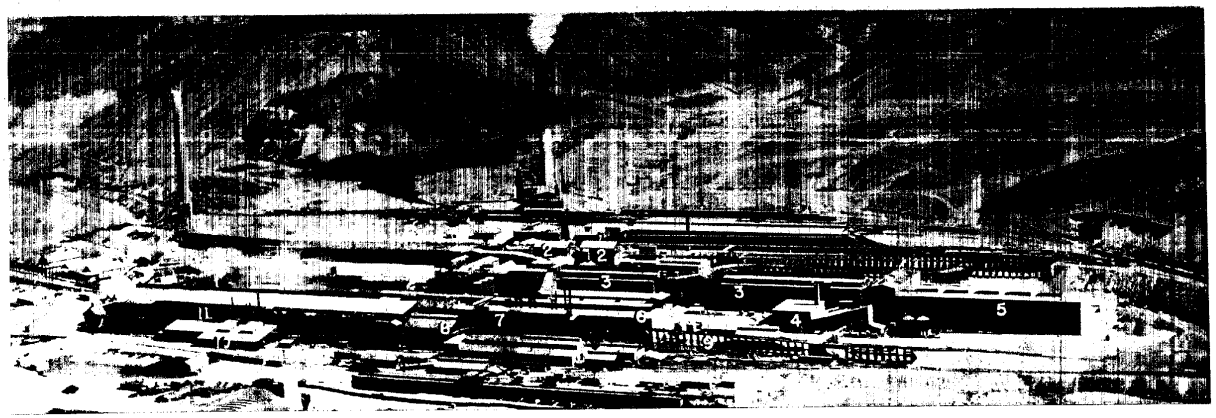
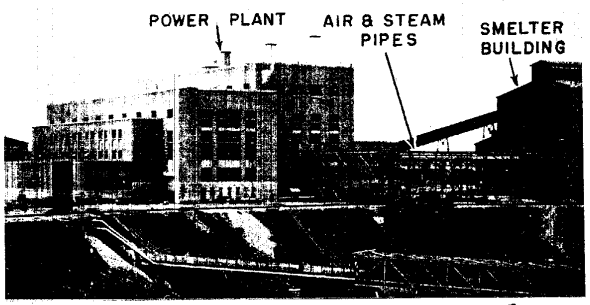
COPPER METALLURGY

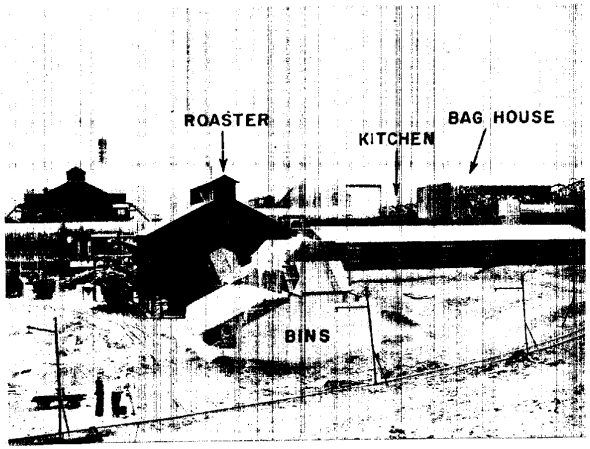
DISTINGUISHING FEATURES OF SMELTERS



1. ORE BINS
2. SAMPLING MILLS
3. ROASTER BUILDINGS
4. SULPHUR PLANT
5. H_2SO_4 CHAMBER PLANT
6. POWER HOUSE
7. COAL BINS
8. PULVERIZER BUILDING
9. COAL TRESTLE
10. CASTING BUILDING
11. SMELTER BUILDING



ABOVE: LARGE MODERN POWER PLANT
BELOW: WHITE ARSENIC PLANT



Smelter Building (Reverberatory Furnace)

(1) Section housing converters similar to blast furnace building.
(2) Section housing reverberatories, lower, wider, and at right angles to converter section.
(3) Roof at far end of reverberatory section elevated to house waste heat boilers - built parallel to converter aisle.
(4) Charge tracks for calcine cars usually run on trestle to top of reverbs at converter end.
(5) Slag tracks, flues, water jacket cooling facilities and pulverized coal conveyor similar to those that service blast furnace building; air compressor pipe leads to converters only.

Stack and Flue System

(1) Large stack or stacks (300 - 600' tall) built to diffuse noxious furnace gases in upper atmosphere; during operations stacks produce heavy white smoke; in Japan smelters often possess a single large stack located on an adjacent hill.
(2) Long wide flues connect stacks with roasting, smelting and converting furnaces; flaring sections of flues mark expansion chambers.
(3) Cottrell placed in flue system between smelter building and stack - housed in small, square buildings (roughly 75' x 65');
(4) Bag houses - see LEAD SMELTER DISTINGUISHING FEATURES.

Slag Dump

(1) Tremendous black dump on waste land adjacent to smelter.

Fuel Supply

(1) Pulverized coal the predominant Japanese blast furnace fuel.
(2) Coal stored either in open piles moved by overhead cranes or in receiving bins built beneath tracks.
(3) Pulverizing plant located in medium sized relatively tall building; connected with blast furnaces (and boiler house if present) by conveyor or pipe.

Power Plant

(1) If it produces most of smelter power, the plant will contain boilers, turbines, transformers, rectifiers or converters, and often air compressors; boiler unit may be a separate heavily constructed building.
(2) Identified by stack, cooling system, and fuel supply - doesn't often possess characteristics of modern stepped boiler, turbine, and switchboard sections.
(3) Smelter may possess sub-station only - with air compressors in separate building similar to boiler house.

By-Products Plants

(1) Sulphuric Acid - see SECTION V.
(2) Arsenic - distinguished primarily by location near stack end of furnace flues; may possess small ore bins and bag house.

Auxiliary Buildings

(1) Include: furnace-brick storage buildings distinguished by low shed-like construction; machine shops distinguished by roof light and constructed to accomodate interior overhead crane; carpenter, electric and railway repair shops; foundries; sampling mill, change houses; warehouses; and offices.

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COPPER METALLURGY (STUDY PHOTOS)

EL PASO COPPER & LEAD SMELTER - STEREO & OBLIQUE VIEWS

1. ORES, FLUXES, AND CONCENTRATES
2. SAMPLING MILLS
3. CRUSHER
4. ORE BINS
5. ROASTER BAG HOUSE
6. LEAD BLAST FURNACE BAG HOUSE
7. LEAD BLAST FURNACE RAW MATERIALS
8. LEAD BLAST FURNACE ELEVATOR
9. NEW ROASTER BLDG.
10. UNUSED ROASTER BLDG.
11. LEAD SINTER BLDG.
12. LEAD BLAST FURNACE BLDG.
13. LEAD DROSSING BLDG.
14. WASTE HEAT BOILERS
15. REVERB. FURNACES
16. CONVERTER AISLE
17. CASTING SHED
18. POWER HOUSE
19. BLAST FURNACE AIR PIPE
20. CHANGE HOUSE
21. SHOPS
22. BRICK SHED
23. SPRAY POND
24. BLAST FURNACE COOLING POND
25. ADMINISTRATION BLDGS.
26. COTTRELL
27. ARSENIC PLANT
28. LEAD SLAG
29. COPPER SLAG

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MIAMI SMELTER

1. ORE-RECEIVING BINS
2. ORE CRUSHER
3. ORE STORAGE BINS
4. CONCENTRATE SAMPLING MILL
5. CONCENTRATE RECEIVING BINS
6. BEDDING BUILDING
7. HEARTH ROASTER BUILDING
8. FLUES
9. WASTE HEAT BOILER SECTION
10. REVERBERATORY FURNACES
11. REVERBERATORY CHARGE SECTION
12. CONVERTER AISLE
13. OIL FEED TANKS
14. CONVERTER DUST CHAMBER
15. BRICK STORAGE SHEDS
16. MACHINE & WOODWORKING SHOPS
17. CHANGE HOUSE
18. OIL STORAGE TANKS
19. STEAM LINES
20. POWER HOUSE
21) BOILER HOUSE
22. COOLING TOWERS
23. SPRAY POND
24. OFFICE
25. SLAG DUMP

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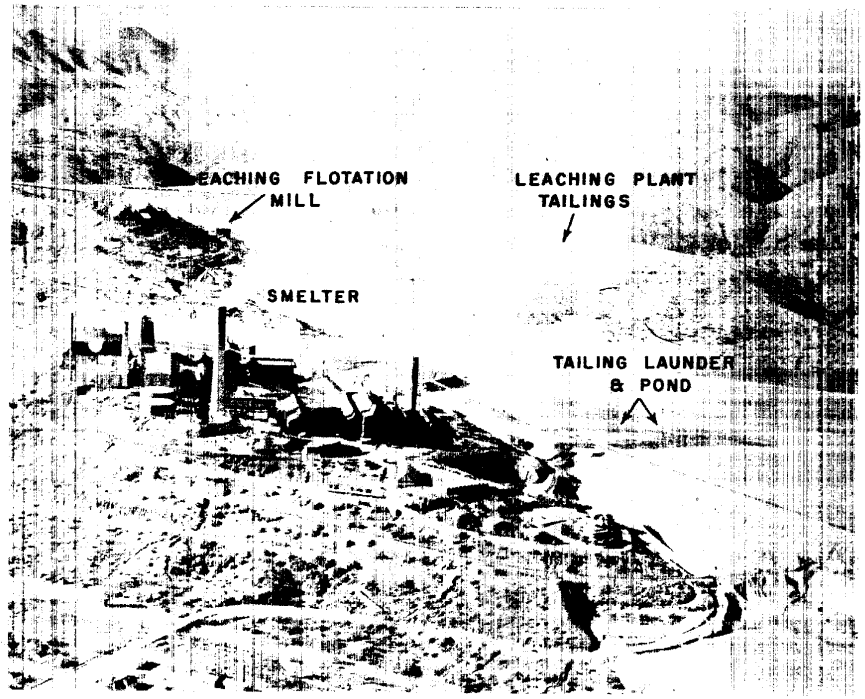
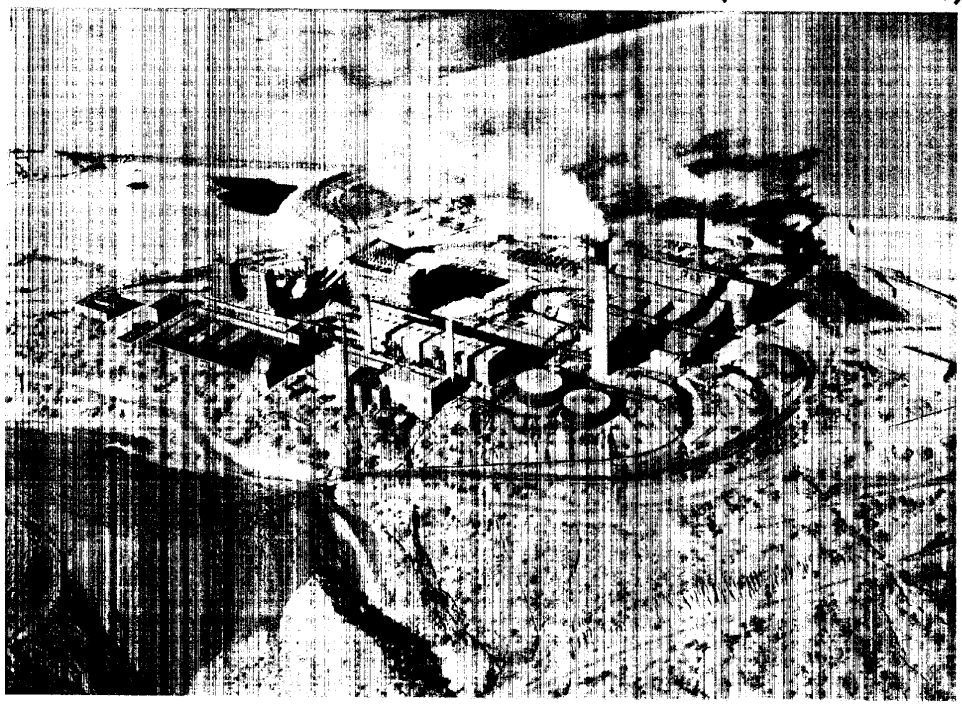
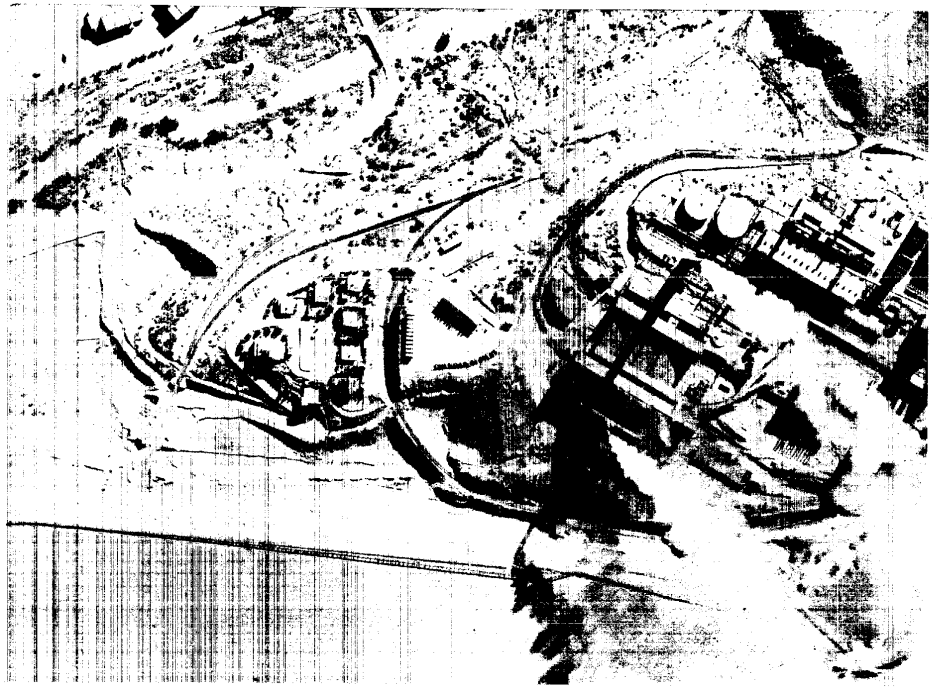
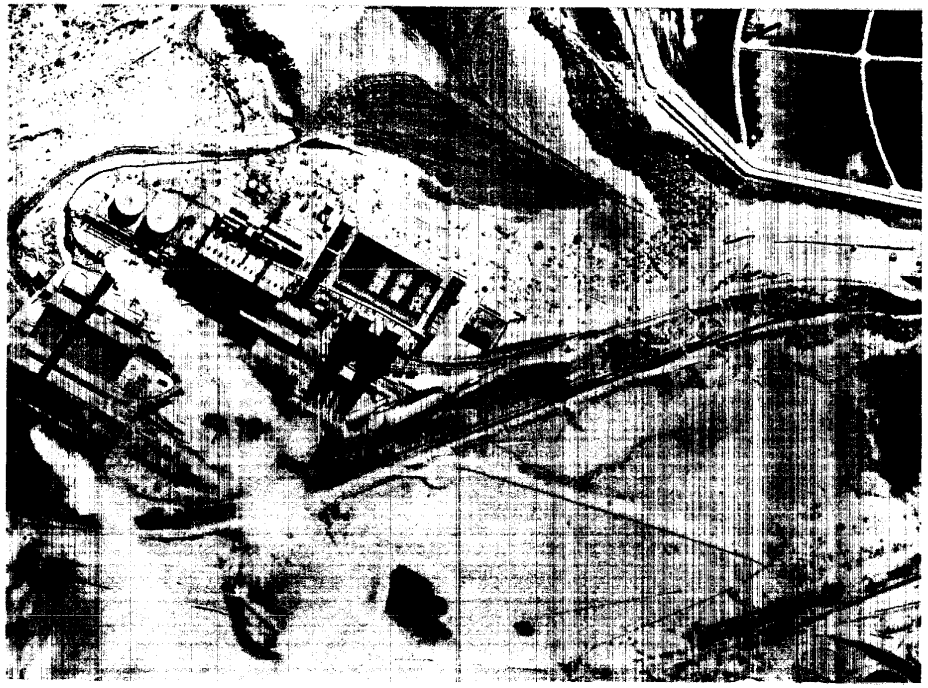
COPPER METALLURGY (STUDY PHOTOS)





MIAMI SMELTER - STEREO & OBLIQUE VIEWS





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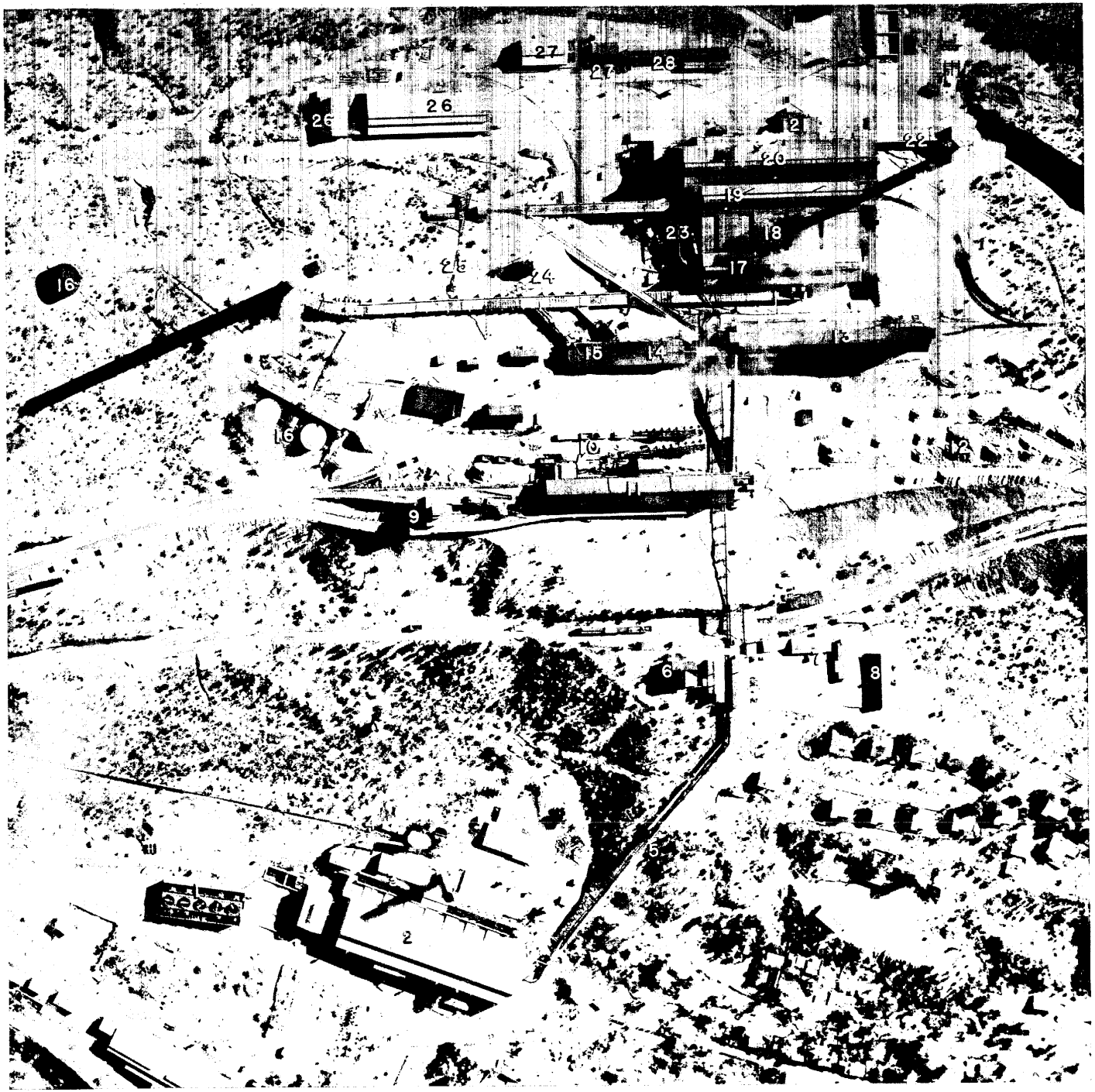

HAYDEN SMELTER

1. COOLING TOWER
2. POWER HOUSE
3. BOILER HOUSE
4. OIL LINES & CHARGING APPARATUS
5. AIR & STEAM LINES
6. OFFICES
7. CHANGE HOUSE
8. WAREHOUSE
9. SAMPLING MILL
10. CRUSHER
11. ORE BINS
12. RAW MATERIAL STORES
13. HEARTH ROASTER BUILDING
14. DUST CHAMBER
15. COTTRELL TREATER
16. FUEL OIL TANKS
17. WASTE HEAT BOILER SECTION
18. REVERBERATORY SECTION
19. REVERBERATORY CHARGE SECTION
20. CONVERTER AISLE
21. CASTING SHED
22. CONVERTER DUST FLUE
23. CONVERTER AIR BLAST LINE
24. SUB-STATION
25. FLUE DUST TRAM
26. MACHINE & BOILER SHOPS
27. WAREHOUSE
28. BRICK & CEMENT STORAGE

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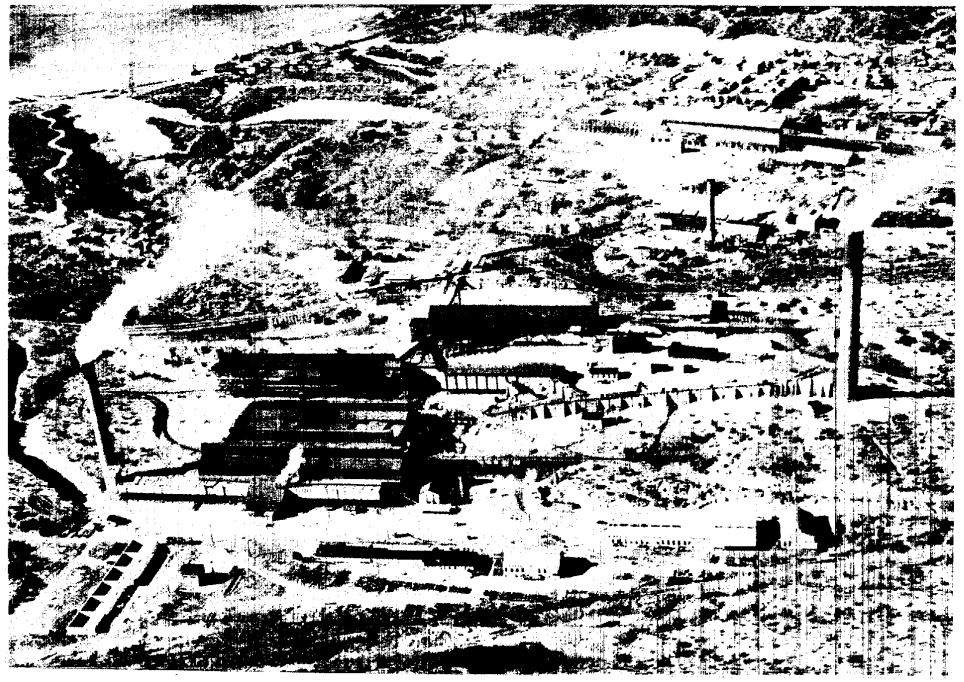
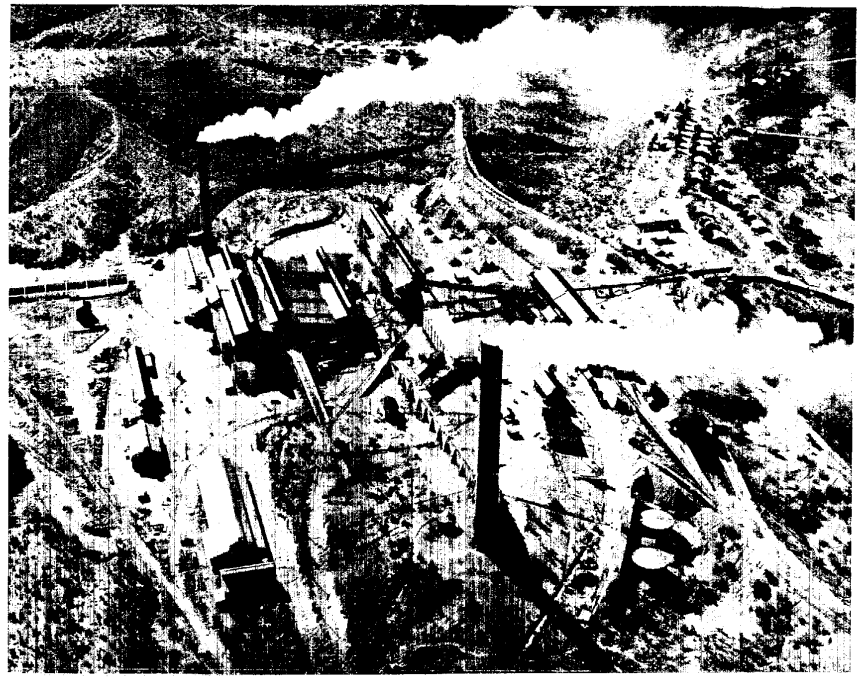
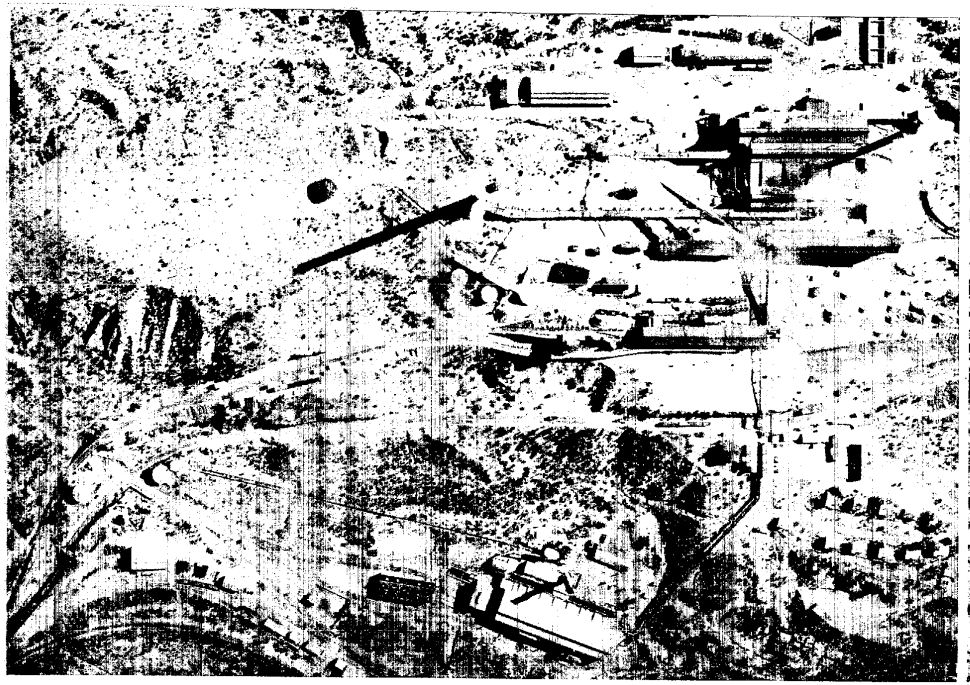
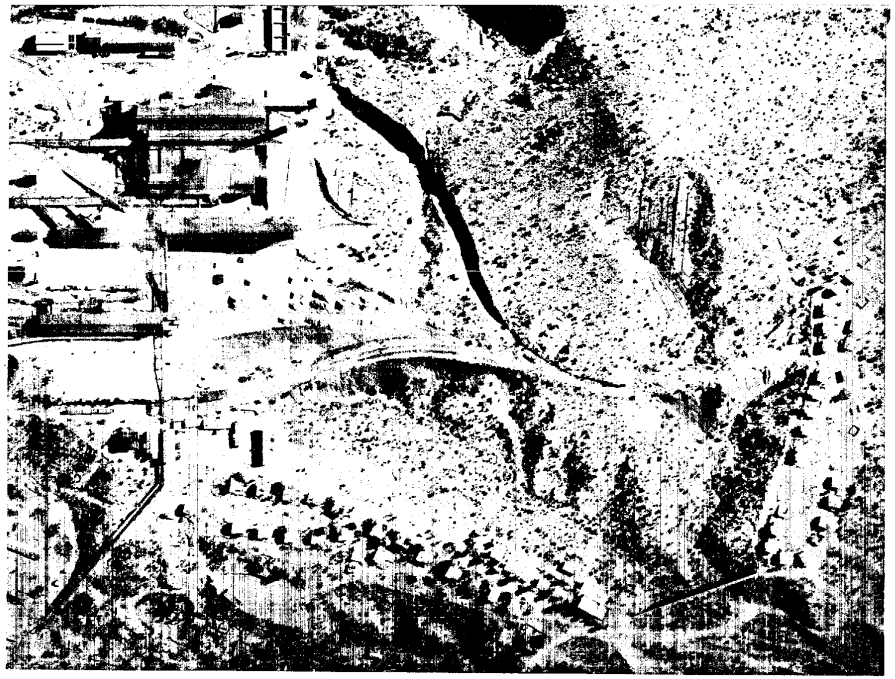
COPPER METALLURGY (STUDY PHOTOS)





HAYDEN SMELTER - STEREO & OBLIQUE VIEWS





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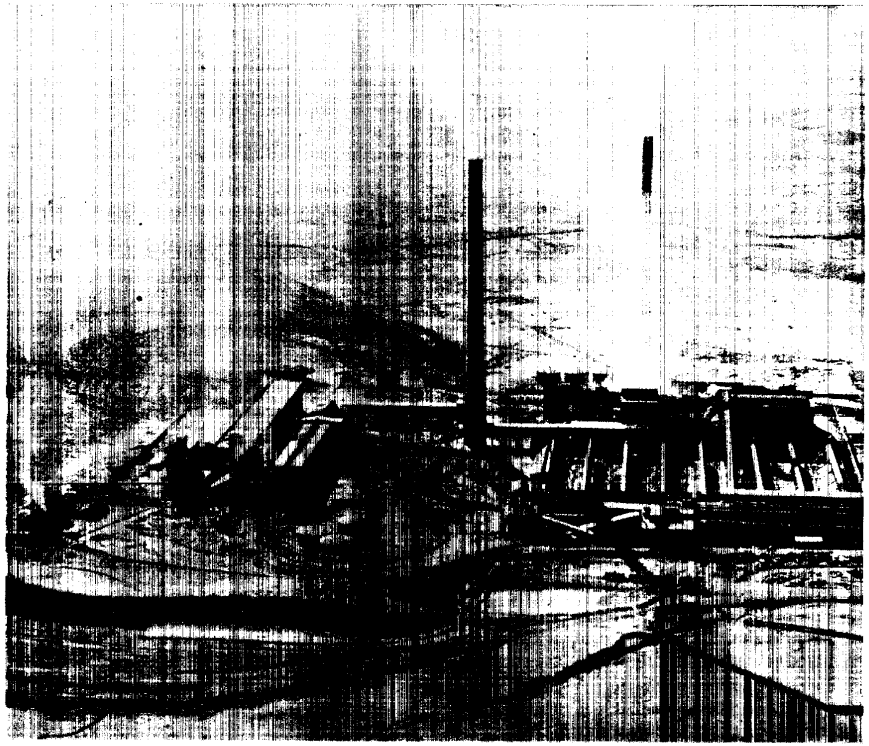
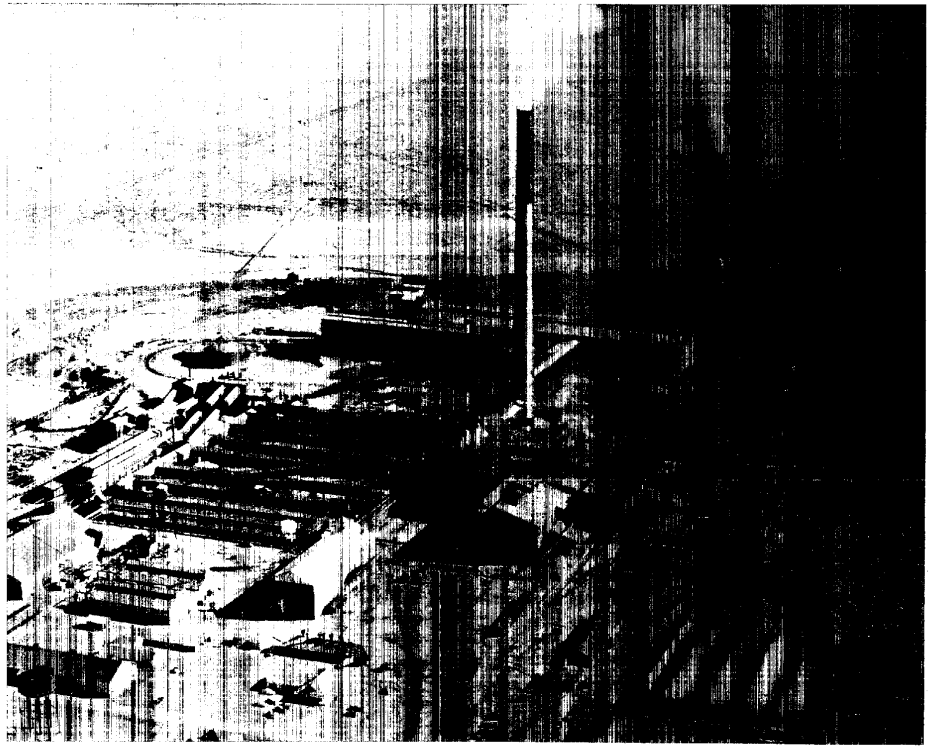
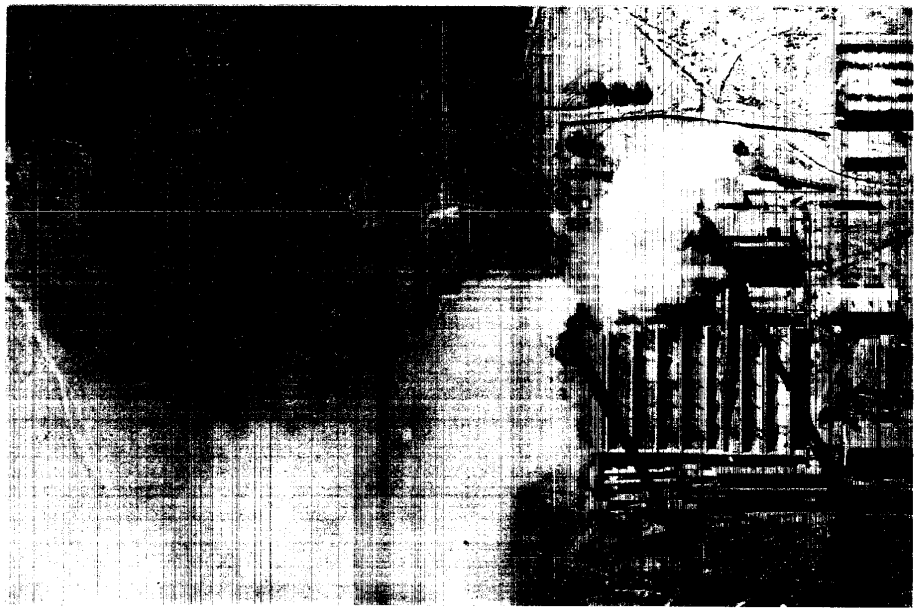
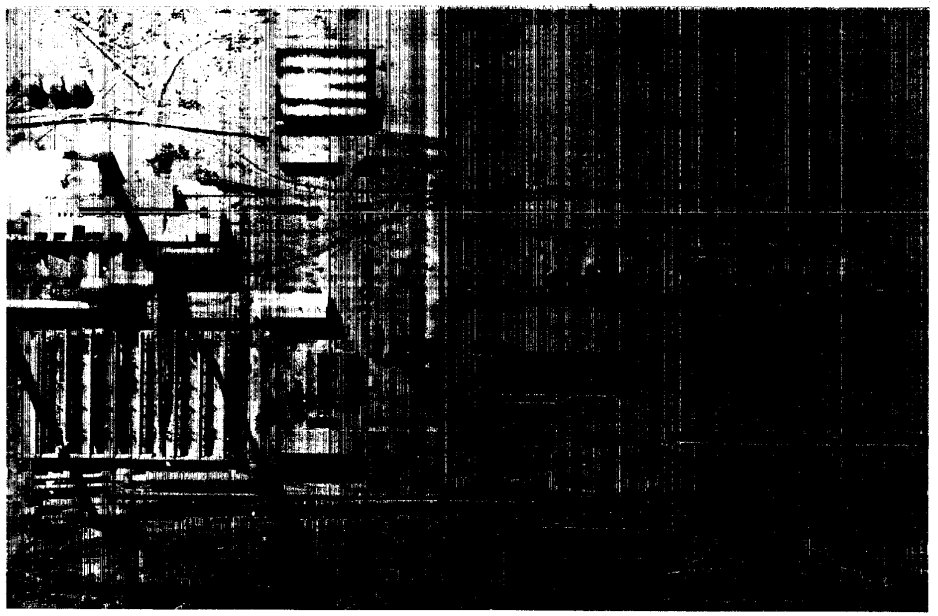




DOUGLAS SMELTER - STEREO & OBLIQUE VIEWS





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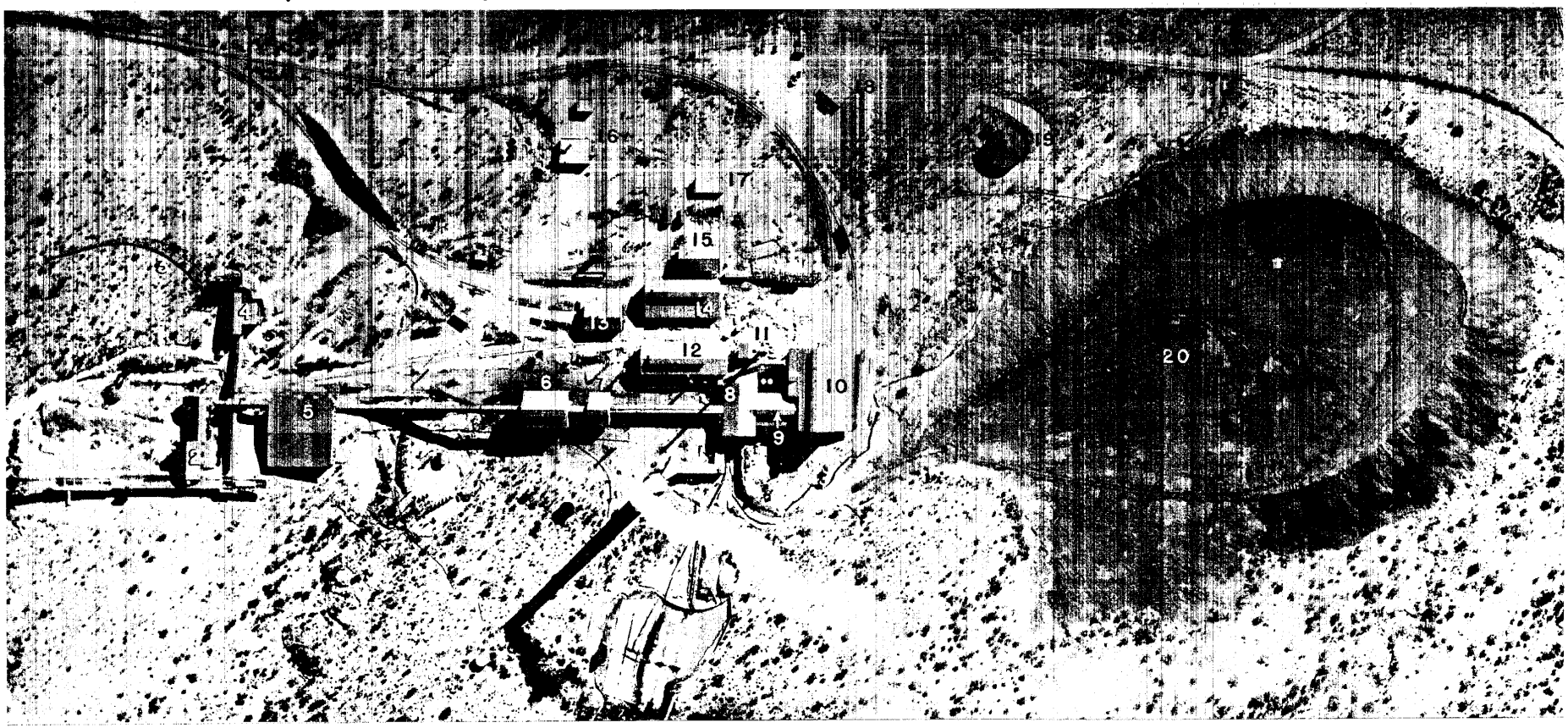
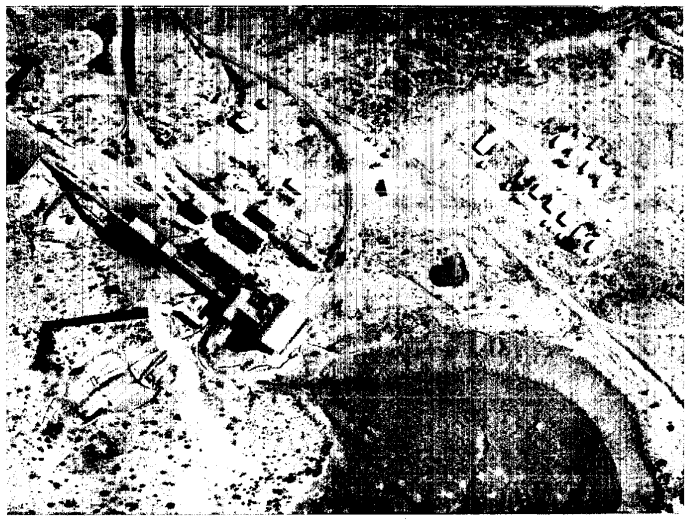
COPPER METALLURGY (STUDY PHOTOS)



SUPERIOR SMELTER - STEREO VIEW & KEY



1. ORE-RECEIVING BINS
2. CRUSHER PLANT
3. CONCENTRATE PIPE LINE
4. FILTER PLANT
5. BEDDING BUILDING
6. HEARTH ROASTER BUILDING
7. COTTRELL TREATER
8. WASTE HEAT BOILER SECTION
9. REVERBERATORY FURNACE SECTION
10. CONVERTER AND CASTING BUILDING
11. BOILER HOUSE
12. POWER PLANT
13. WAREHOUSE
14. MACHINE SHOPE
15. ENGINE HOUSE
16. ASSAY OFFICE
17. CHANGE HOUSE
18. GENERAL OFFICE
19. FUEL OIL
20. SLAG DUMP

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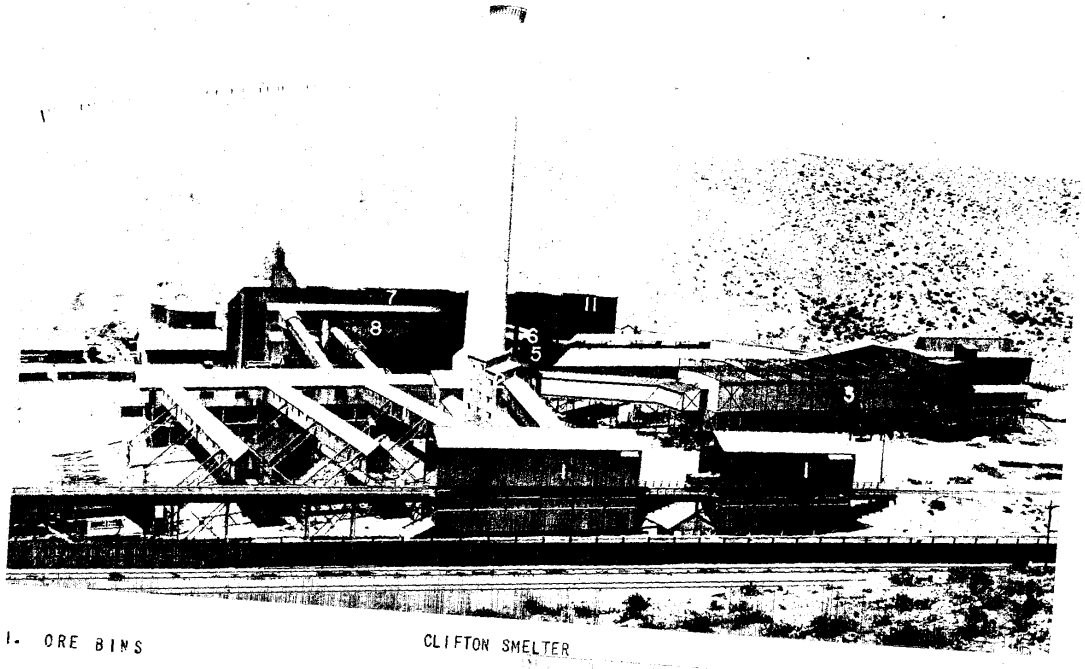
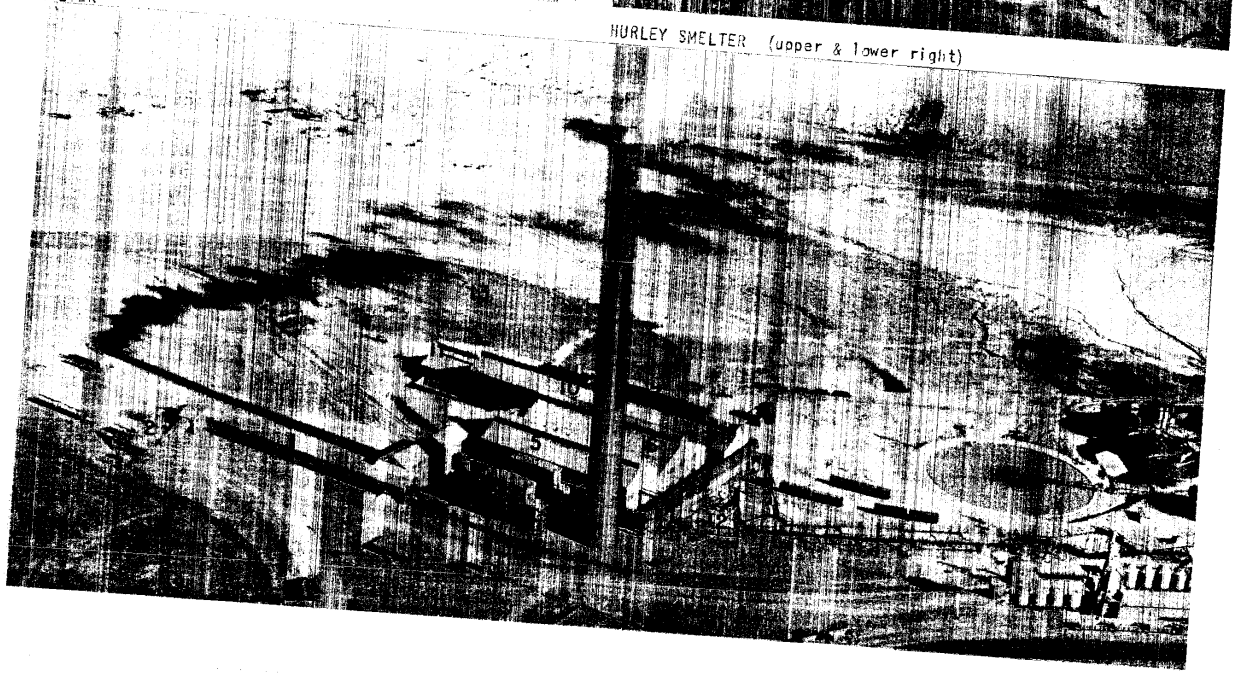
COPPER METALLURGY (STUDY PHOTOS)



CLIFTON SMELTER

HURLEY SMELTER (upper & lower right)



1. ORE BINS
2. CRUSHER
3. DUST CHAMBER
4. HEARTH ROASTERS
5. WASTE HEAT BOILERS
6. REVERBERATORY FURNACES
7. CONVERTER AISLE
8. CONVERTER FLUE
9. COTTRELL TREATER
10. MACHINE SHOPS
11. CASTING SECTION
12. STEAM AND AIR PIPES
13. SLAG DUMP

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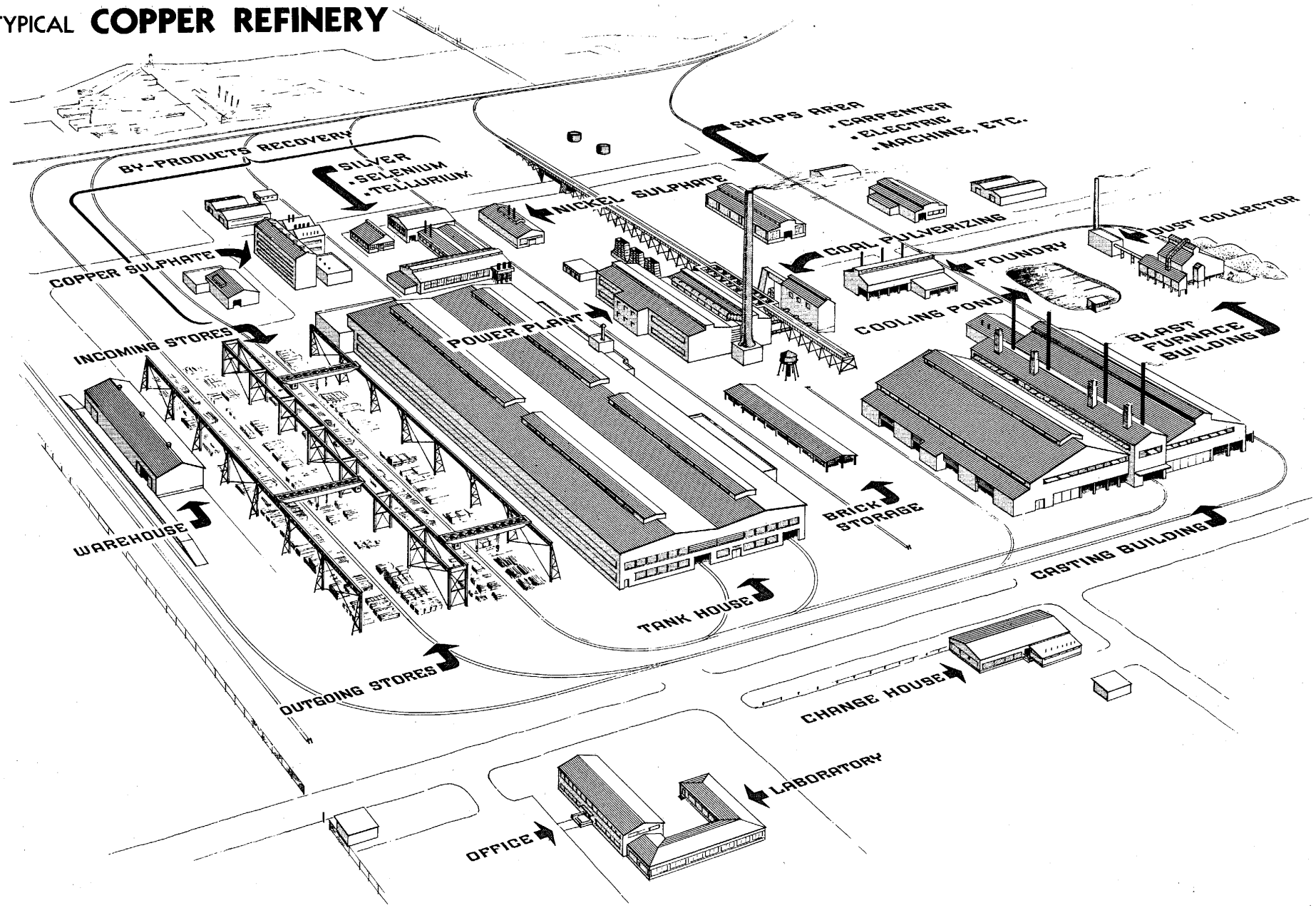
TYPICAL **COPPER REFINERY**



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REFINING THE CRUDE SMELTER COPPER

THE PURPOSE OF REFINING

Blister copper, as it is produced at the smelter is slightly over 98% pure. This is generally too poor in quality for direct use and must be further purified by refining to 99.9% prior to commercial fabrication. The impurities present in smelter copper fall into two classes: (1) base metals and non-metals such as sulphur, iron, lead, arsenic, antimony, zinc, nickle, cobalt, selenium and tellurium which must be removed because of their harmful effects upon the properties of copper, and (2) precious metals as gold, silver, platinum, and palladium which are not usually harmful to copper but have sufficient value to pay for their separation.

Removal of impurities is accomplished by fire refining and electrolytic refining. Fire refining removes impurities which combine readily with oxygen to form slags, while electrolytic refining eliminates the impurities which cannot be oxidized prior to the copper, that is, primarily the precious metals and bismuth.

The normal sequence of operations in American copper refining is: (1) fire refining of smelter copper in an anode furnace followed by casting of the anode bars used in electrolytic refining (2) electrolytic refining of anode bars to produce cathodes of electrolytic copper (3) remelting and further refining of cathodes, followed by casting into market shapes. In Japan although all the copper produced is subjected to steps (2) and (3) of the American process, step (1) is usually skipped and blister from converters is cast directly into anodes.

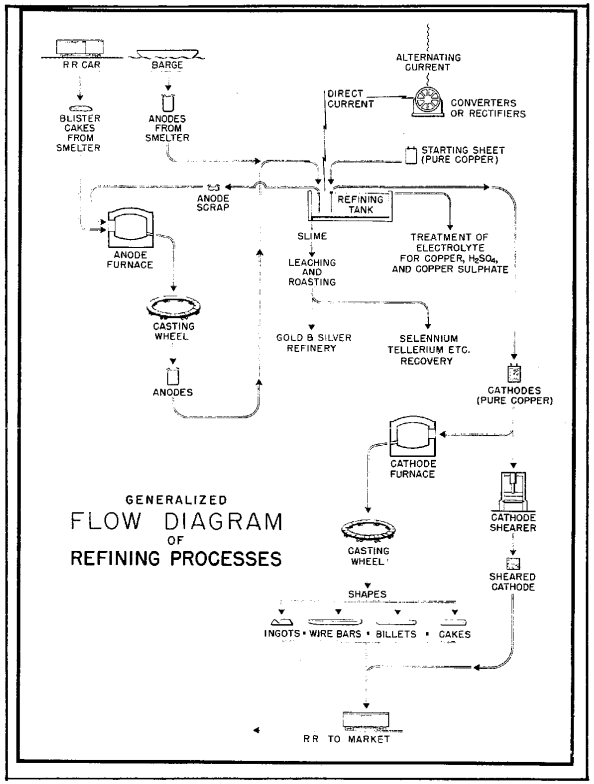
FIRE REFINING IN THE ANODE FURNACE

Fire refining in the anode furnace and the subsequent casting of anode bars may be carried on at either the smelter or the refinery. Operations are essentially the same at each, however, and can be divided into a charging stage, an oxidation stage, a poling stage, and a casting stage.

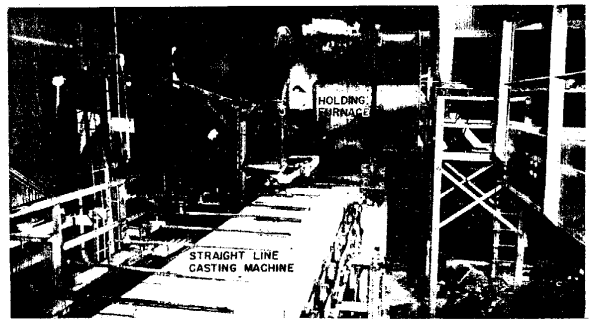
Refining Operations: Anode furnace charges at the smelter consist of liquid blister from the converter, while charges at the refinery are made up of solid blister cakes. Because the heat of liquid blister is nearly sufficient to maintain furnace baths in a molten state during refining without the addition of fuel, anode furnaces at the smelter serve primarily as holding furnaces. At the refinery, however, blister cakes enter the furnace hearth cold and a considerable amount of heat must be generated for melting.

When the charge has become completely molten it is oxidized with an air blast which attacks impurities and brings them to the surface as slag. Slag skimmings are small in quantity and are either returned to the converter or discarded. During oxidation blister copper in the anode furnace is partially changed to cuprous oxide and must be reduced back to metallic copper by "poling". This reduction is accomplished by thrusting green tree trunks, 6"-10" in diameter, into the molten charge. The heat of the liquid causes destructive distillation of the wood, and the carbon gases evolved reduce the oxide to metallic copper which is ready for casting.

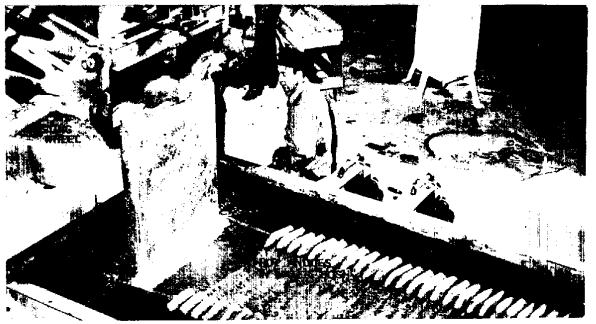
POLING AN ANODE FURNACE



Modern casting of copper shapes is accomplished primarily by mechanical methods. The essential machinery used includes a pouring ladle attached to the furnace tap hole, a machine for bringing molds under the ladle (normally a wheel or straight line mechanism), a water tank or spray for cooling, and a crane for moving finished bars to rail cars. To keep copper from sticking in the anode molds as they are refilled in transit through the casting machine, a bone ash solution is sprayed in each prior to pouring.



STRAIGHT LINE CASTING



COOLING ANODES IN A WATER BATH

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CASTING ANODES ON A WHEEL

Refining Equipment: Anode furnaces are of two types. The most common type which is used at both smelters and refineries is a brick reverberatory structure about 50' long. It is shorter than the copper matte furnace but similar in its construction. The other type, used only at the smelter, is a brick lined steel furnace similar to a barrel converter without the hood. The reverberatory furnaces used at the refinery may be equipped with waste heat boilers to conserve the heat carried off in furnace gases.

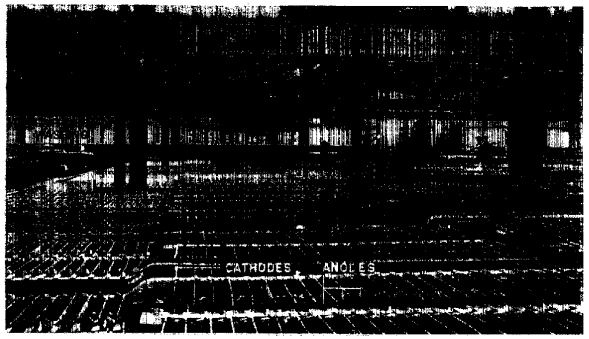
When fire refining operations take place at the smelter, one or two anode furnaces, a water bosh, and a single casting machine are required. All of these are located at one end of the converter aisle. At a refinery, this basic equipment is housed in the casting building. The furnaces are arranged in a row in the center of the building. On one side of the row, long-armed electric charging machines travel on rails from furnace to furnace picking blister cakes from narrow gauge flat cars and thrusting them through furnace charging doors. On the opposite side of the row, a large overhead crane for loading finished shapes as they come from casting machines runs the entire length of the building.

CHARGING A FIRE REFINING FURNACE

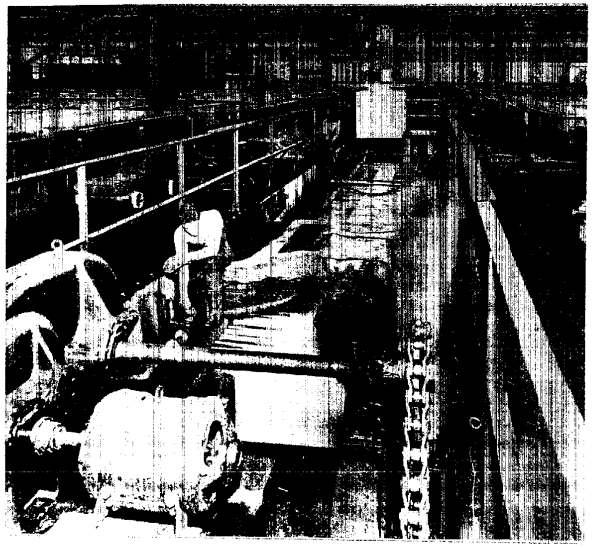
ELECTROLYTIC REFINING

Copper anodes whether cast from blister or from fire refined copper are finally purified by an electrolytic process that releases precious metals and small quantities of base metals. For purposes of study the stages of electrolytic refining are best considered under three headings: (a) electrolytic refining of anodes, (b) preparation of cathode copper for commercial use, and (c) treatment of slimes and electrolyte.

Electrolytic Refining of Anodes: The electrolytic cell used for the electrolytic refining of anodes is a lead-lined wooden or concrete tank filled with copper sulphate solution which serves as the electrolyte. The electrodes may be connected either in multiple or series.



The multiple system is most commonly used. In this system the cast anode bar acts as the positive electrode, and a starting sheet of pure copper serves as the negative electrode. Starting sheets are thin plates of electro-deposited copper made in special electrolytic tanks known as stripper tanks. In the multiple arrangement, the current is passed through two long bus bars; all the anodes are attached to one bar, all the cathodes to the other. Operations begin with the placing of new anodes and starting sheets in the tanks. Anodes are handled by means of an overhead crane equipped to move an entire tankload at one time. Starting sheets, on the other hand, are usually placed in a tank one at a time following the setting of the anodes. When the current is on, impure copper from the anode goes into the electrolyte, and pure copper from the electrolyte is deposited on the cathode (Starting Sheets). The growth of the cathodes to the required size (approximately $\frac{1}{2}$ inch thick) takes from 6 to 15 days after which they are removed, washed of slime and sent to the cathode furnace.



WASHING CATHODES AFTER REMOVAL FROM ELECTRODE TANKS

In the series arrangement, the back of each anode serves as the cathode of the preceding anode. The electric current enters the first anode and leaves at the last cathode. In this way, the current passes through each anode and cathode in succession. The operation of the cell, otherwise, is generally the same as that of the multiple system.

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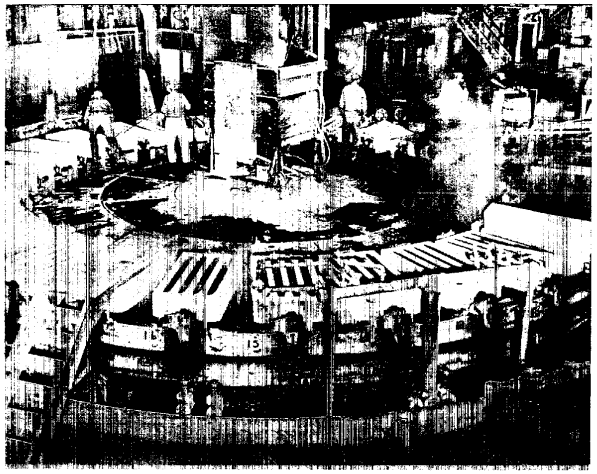
Preparation of Cathode Copper for Commercial Use: Copper cathodes must be converted into usable copper shapes before they are ready for commercial fabrication. The simplest conversion consists of shearing the cathode sheets into smaller pieces for use in alloy casting furnaces and foundries. For operations where more precise shapes, i.e., wire bars, cakes, billets, and ingots - are required, cathodes are melted and refined in reverberatory (cathode) furnaces.



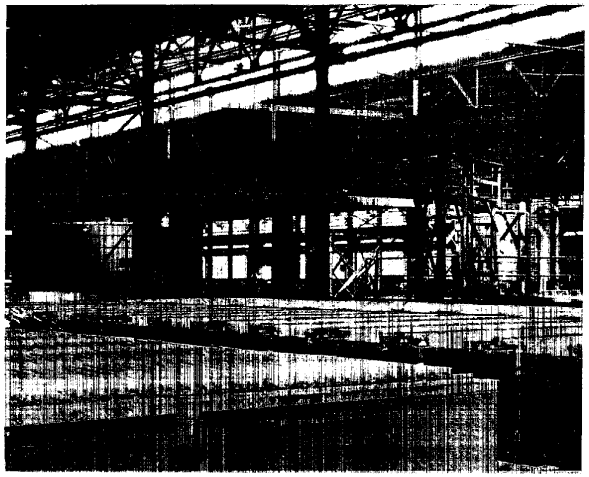
CASTING WHEEL FOR WIRE BARS

The stages of cathode furnace operations are generally the same as the four described in connection with the furnace. In fact, at some refineries anode and cathode fire refining operations are carried on interchangeably in the same furnaces and casting is done on the same wheel merely by shifting the molds.

The actual casting of wire bars, cakes, and billets requires great care in order to insure a smoothly finished product that will not become defective during fabrication. For the same reason after casting, the exposed surfaces of bars, cakes, and billets must often be scalped of the black oxide which forms during cooling. Scalping is accomplished by machines that either cut or grind the thin oxidized surface from the copper shape.

Treatment of Slimes and Electrolyte: In the process of electro-deposition the copper anode is rid of its impurities in two general ways: (1) by dissolving them into the electrolyte, and (2) by dropping them to the bottom of the tank as solid particles of anode mud. The impurities usually make up about 1.5% of the total anode by weight.

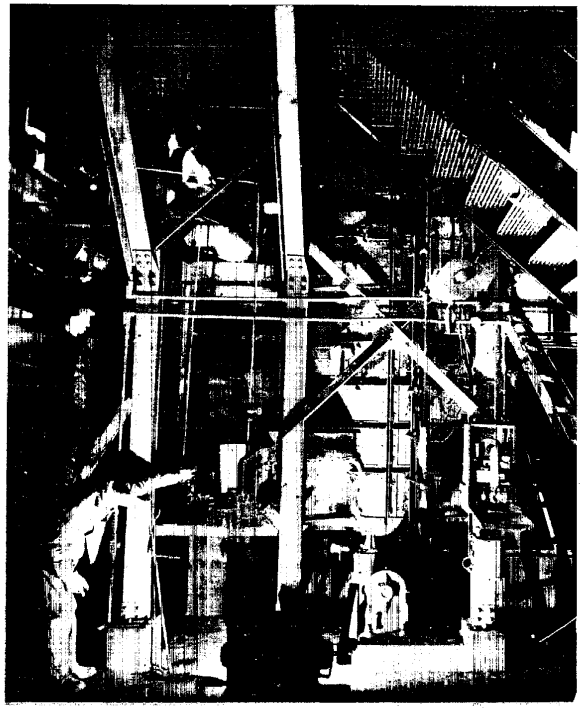
Both the electrolyte and the anode slimes are treated further for recovery of by-products. In actual practice, however, some refineries do a more complete job of recovery than others, depending upon the mineral content of electrolyte and slimes, the market for by-products, and the unit cost of treatment. Nearly all of the refineries in Japan treat slimes and electrolytes exhaustively because there are a limited number of plants and because the available ores are relatively rich in by-products.



ELECTROLYTE STORAGE TANKS

The handling of the electrolyte occurs in two stages. First, the electrolyte is kept in constant circulation by a system of pumps and storage tanks. This prevents the precipitation of copper sulphate crystals from the saturated solutions in the tank. The pumps and tanks are located within the tank house or along its periphery. Secondly a certain amount of the solution is bled regularly to recover its acid and copper content. This prevents the electrolyte from becoming over saturated and halts the flow of current from anode to cathode. The recovery of copper is accomplished either by electrolysis with an insoluble lead anode or by a process of crystallization that precipitates the metal in the form of copper sulphate crystals.

Anode slimes yield various proportions of precious metals, selenium, tellurium, nickel-sulphate, nickel, and a few other by-products. The details of recovery and the products obtained are different for each refinery. Furthermore, the processes employed are too comelicated to describe here. The plants used for treatment occupy only a small portion of the total refinery area and are not essential to the flow of production. Stated generally, however, all refineries



ROASTING LEACHED ANODE SLIMES

employ a combination of several or all of the following processes in the treatment of their anode slimes: crystallization, leaching, electrolysis, cementation, and distillation. Crystallization, leaching, and cementation operations are activated by either furnace heating or chemical combination and take place in a variety of enclosed or open iron, wood, and steel tanks. Electrodeposition follows the same principle used in the electrolytic tank house, but the process is carried out on a much smaller scale and employs different types of anodes and electrolytes. Distillation which takes place on an extremely small scale is used primarily to recover selenium of high purity.

DISTINGUISHNG FEATURES OF REFINERIES

SUMMARY OF FEATURES

There are no outstanding features which will invariably distinguish a copper refinery from other types of industrial plants. However, there are a number of features which, when considered together, do give some idea of the purpose of the refining buildings. Perhaps the best distinguishing feature is the casting building

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DISTINGUISHNG FEATURES OF REFINERIES

with its characteristic furnace stacks, while the largest and most noticeable feature is the electrolytic tank house. The tank house and casting building will be associated with a large power house or sub-station, and linked with storage yards which contain metallic shapes and are serviced by overhead cranes.

Other more or less characteristic installations that may be present among refining buildings include a secondary smelter building with representative stack, ore bins, cooling flues, and bag house; small by-products plants (silver parting plant etc.); fuel storage facilities; a pulverizing plant (if fuel is coal or pitch); and the usual auxiliary shops and offices. The location of a copper refinery is dictated generally by the proximity of accessible manufacturing markets, cheap power, and rail and shipping facilities.

DETAIL OF FEATURES

Casting House

(1) Usually the second largest structure at refinery

(2) Identified by stack (or stacks) which services anode and cathode furnaces.
   (a) Older houses possess stacks for each furnace - sometimes two, one for servicing the waste heat boiler and one for use when boiler is cut out of operation.
   (b) In more modern houses furnaces are serviced by downcomers which are connected to a single tall stack by a balloon flue.
   (c) Number of stacks, pairs of stacks, or downcomers indicates roughly the number of furnaces.

(3) Nearly always one casting building - sometimes more than one.

(4) Dimensions of building vary with the number of furnaces it contains; Japanese casting buildings are probably smaller than those in U.S., for Japs refine and cast only cathodes while Americans refine and cast both anodes and cathodes.

(5) Construction may be multi-bayed with a section for charging operations, a section for furnaces, and a section for casting and shipping; or single-bayed with all operation housed under one wide span.

(6) Roofs of operative buildings are light in tone from bone ash dust that settles out of casting steam.

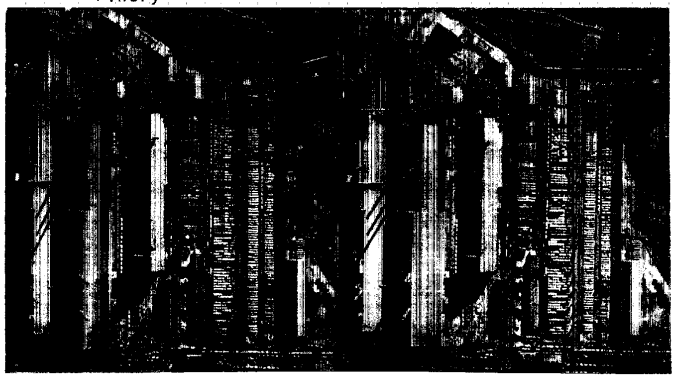
Tank House

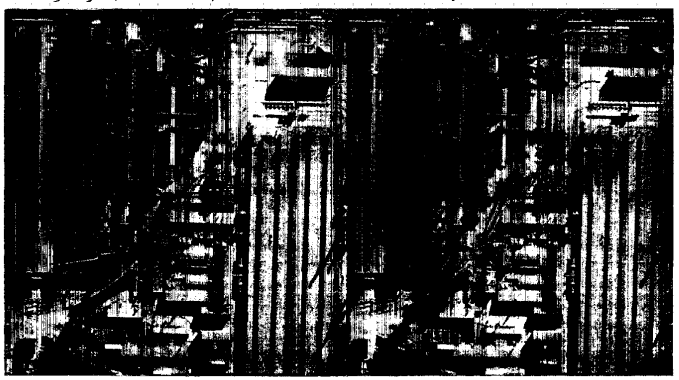
(1) Largest building at refinery (usually only one although several are not uncommon) - approximately 30' high to accomodate overhead cranes for interior movement of anodes and cathodes.

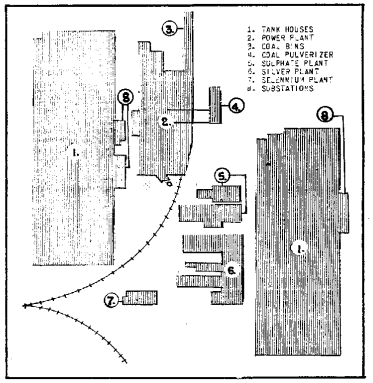
(2) Domestic tank houses are rectangular multi-bayed structures; Japanese houses are more often single-bayed structures of great length.

(3) Overhead wires are sometimes apparent leading from power station to tank house. Occasionally lines converge on small sub-stations, along tank house periphery, that contain transformers and converters or rectifiers.

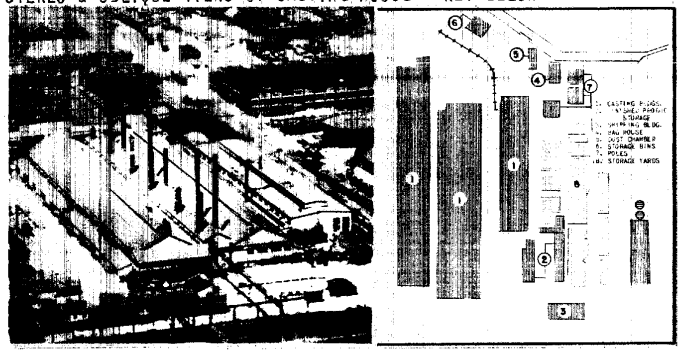
(4) Storage yards for copper shapes often adjacent and always linked to tank house by narrow gauge tracks.



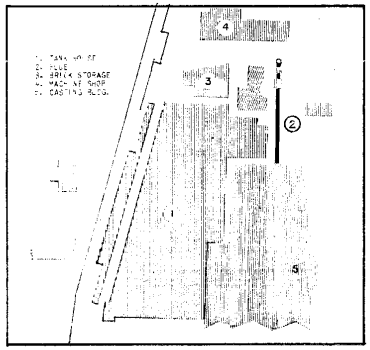




STEREO & OBLIQUE VIEWS OF CASTING HOUSE - KEY BELOW



ABOVE: CASTING HOUSES, BELOW TANK HOUSE



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Power Plant

(1) If responsible for any large percentage of total power used, plant contains boilers, turbines, transformers, and rectifiers or converters. Boiler unit often a separate building.

(2) If outside sources used - power unit may be merely one sub-station building containing transformers etc.

(3) Plants at older refineries do not have stepped boiler, generator, and switchboard units, but most possess usual large stack, fuel source, and cooling equipment .

Fuel Storage

(1) Jap refinery fuels include coal, oil, charcoal, and pitch.

(2) Coal stored in large piles served by overhead conveyor or in conventional ore bins filled from elevated tracks.

(3) Coal pulverizing plant located adjacent to coal storage facilities and sometimes connected with power plant by conveyors or compressed air pipes.

(4) Oil storage tanks often available as auxiliary source of fuel.

(5) Pitch pulverized in plant similar to one used for coal.

Smelter Building

(1) Not always present; if present it is used to smelt copper reverts such as anode furnace slag; usually contains one blast furnace.

(2) Distinguished by:

(a) Adjacent raw material bins (sometimes housed) for coke, silicates, and reverts.

(b) Elevator housing or conveyor for charging blast furnace (also not always visible).

(c) Flues running from blast furnace to bag house and stack.

(d) A small bag house and a medium sized (100-200') stack .

Storage Yards

(1) Storage yards serviced by overhead crane present at nearly every refinery.

(2) Empty storage yards not necessarily an indication of shut down, for schedules of war-time production and shipping are sometimes so closely synchronized that stock piles in yards are always nil.

(3) Yard products include - copper shapes (wire bars, anodes, blister cakes); poles for poling; scrap iron for cementation; blast furnace materials; fuels; parts for machine shops; lumber; extra casting molds etc.

(4) Poles and fuels the only easily identifiable products; blister cakes sometimes distinguished by light reflected from flat surfaces.

(a) Cathodes not stored in open, but sometimes seen on flat cars moving about yard.

(b) Finished shapes often stored in sheds.

By-Product Plants (Silver Parting - Copper sulphate Selennium - Tin - Nickel - Sel. etc.)

(1) Plants located in small additions to tank house or in small separate buildings measuring from 50' x 50' to 150' x 150'.

(2) Silver-Parting Plant occasionally identified by Cottrells, cooling flues, and scrubber towers used to treat valuable furnace smokes and gases.

(3) Other by-products plants occasionally distinguished by small, short stacks scattered over roofs. These often seen eliminating steam.

Transportation Facilities

(1) Both rail and shipping terminals commonly available to refineries.

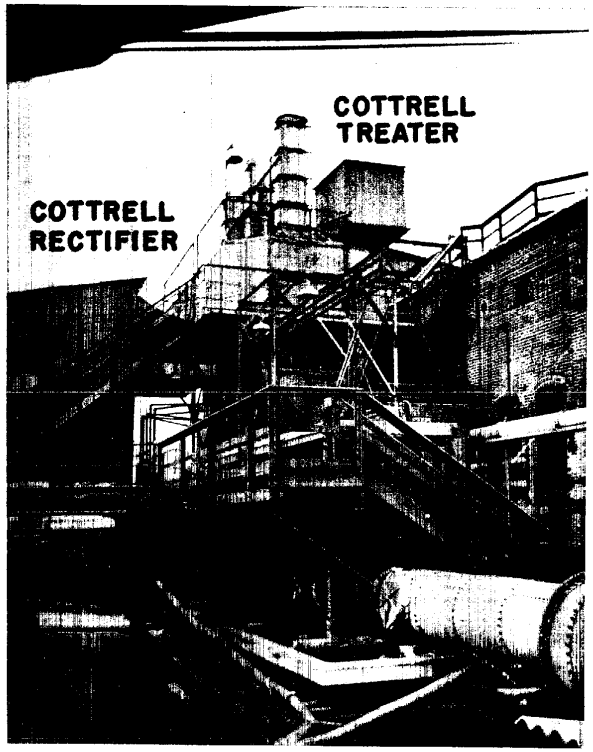
(2) Internal transport provided by system of narrow gauge tracks.

Auxiliary Buildings

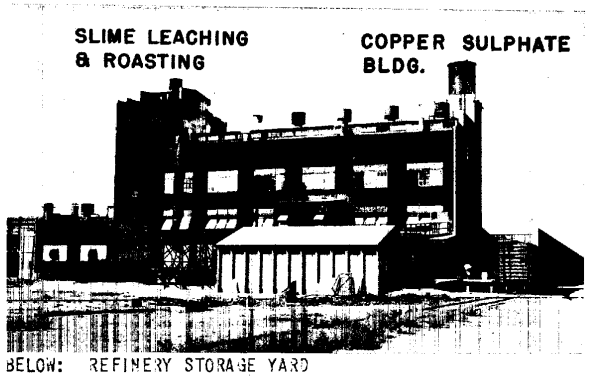
(1) Include: storage buildings for finished shapes, furnace bricks, scrap etc; shops for machine repair, carpentry, electrical work, narrow gauge engine repair etc; foundries; change houses; and office building.

(2) Brick storage buildings low shed-like structures; office buildings sometimes multi-storied; machine shops built with monitor rooflights; other buildings vary at each refinery - identified only by adjacent stores etc.

SILVER PARTING DUST RECOVERY EQUIPMENT



BY-PRODUCTS BUILDING



BELOW: REFINERY STORAGE YARD

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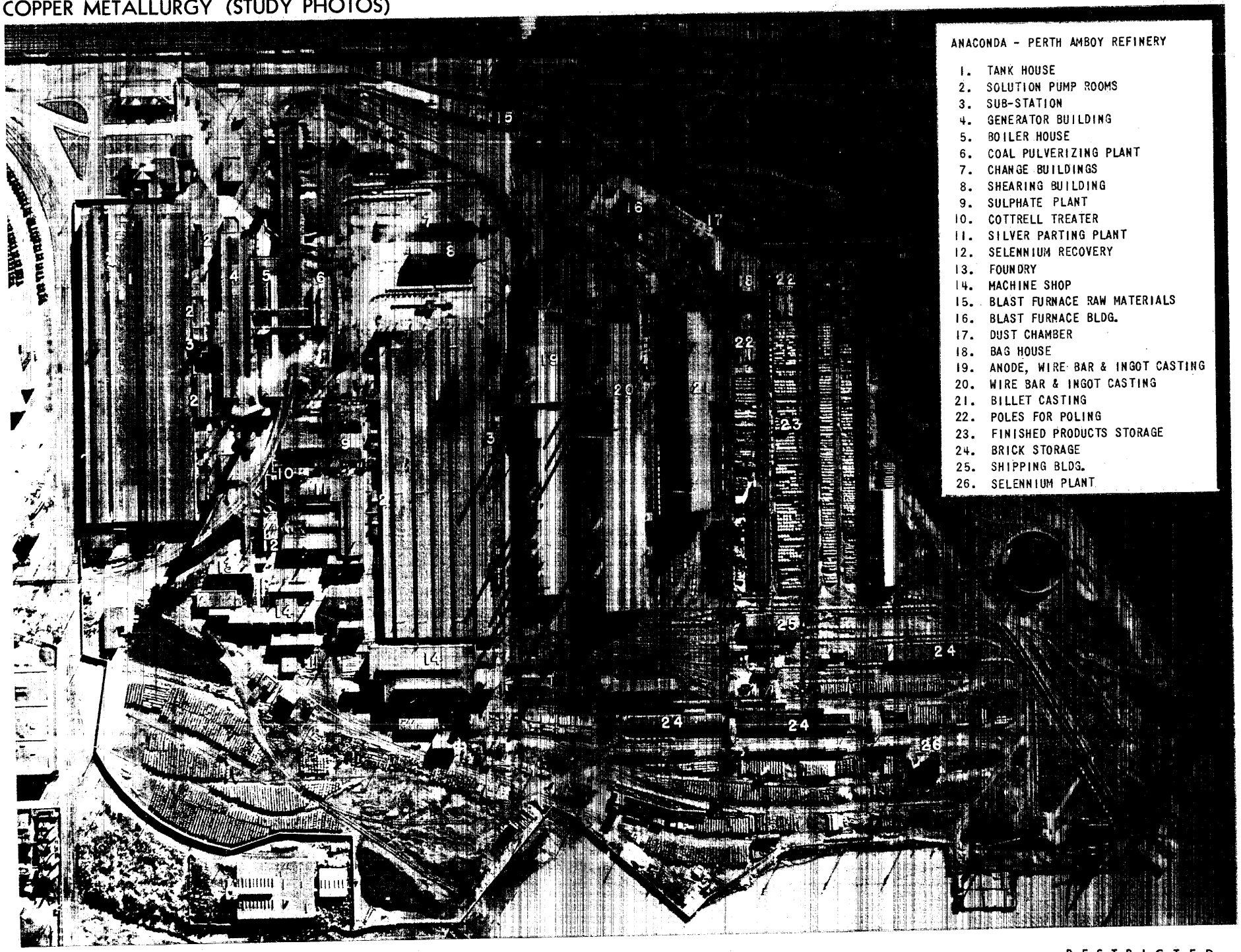
COPPER METALLURGY (STUDY PHOTOS)



ANACONDA - PERTH AMBOY REFINERY

1. TANK HOUSE
2. SOLUTION PUMP ROOMS
3. SUB-STATION
4. GENERATOR BUILDING
5. BOILER HOUSE
6. COAL PULVERIZING PLANT
7. CHANGE BUILDINGS
8. SHEARING BUILDING
9. SULPHATE PLANT
10. COTTRELL TREATER
11. SILVER PARTING PLANT
12. SELENNIUM RECOVERY
13. FOUNDRY
14. MACHINE SHOP
15. BLAST FURNACE RAW MATERIALS
16. BLAST FURNACE BLDG.
17. DUST CHAMBER
18. BAG HOUSE
19. ANODE, WIRE BAR & INGOT CASTING
20. WIRE BAR & INGOT CASTING
21. BILLET CASTING
22. POLES FOR POLING
23. FINISHED PRODUCTS STORAGE
24. BRICK STORAGE
25. SHIPPING BLDG.
26. SELENNIUM PLANT

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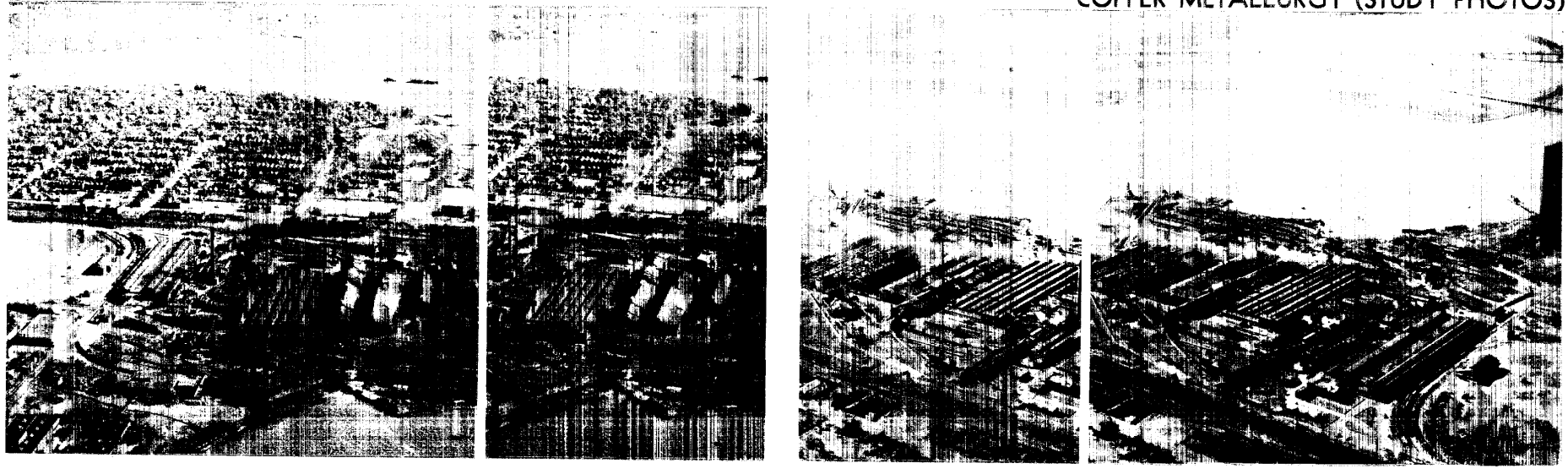
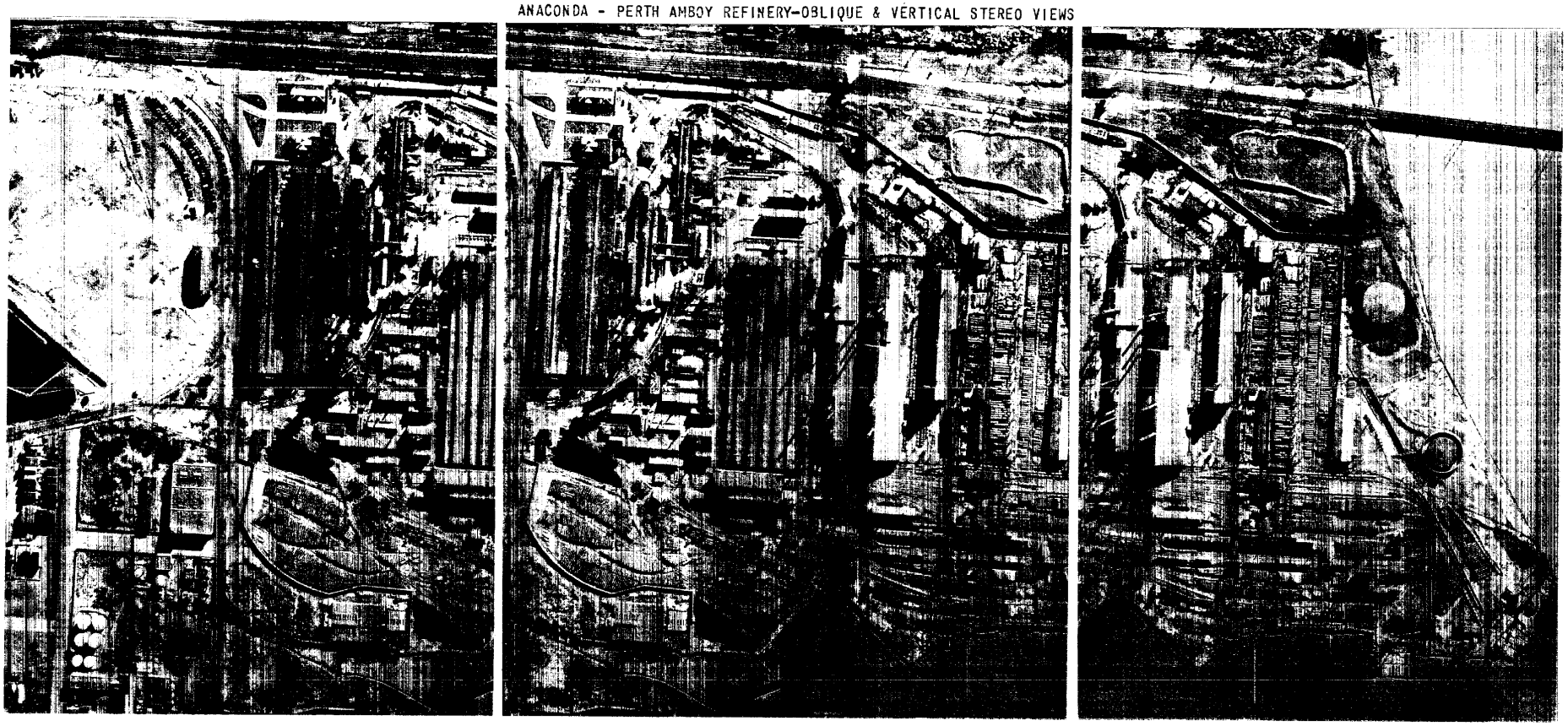


ANACONDA - PERTH AMBOY REFINERY-OBLIQUE & VERTICAL STEREO VIEWS



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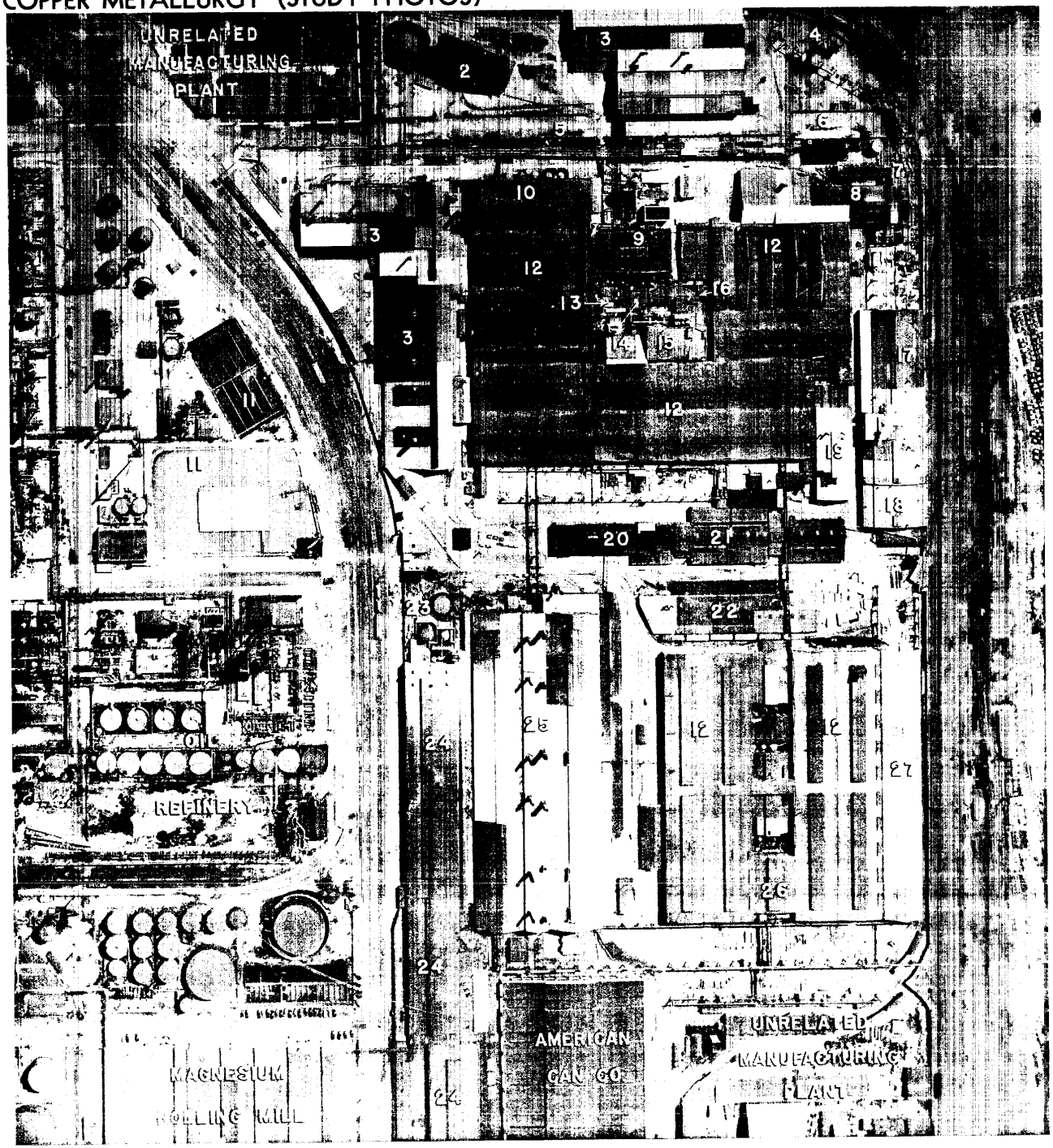
COPPER METALLURGY (STUDY PHOTOS)



A.S. & R. - BALTIMORE REFINERY

1. FUEL STORAGE
2. SCRAP STORAGE
3. UNUSED CASTING BLDG. (NOTE LACK OF BONE ASH DUST ON ROOF)
4. SLAG CRUSHER
5. BLAST FURNACE RAW MATERIALS BINS
6. FLUX CRUSHER BLDG.
7. BLAST FURNACE DUST CHAMBER
8. BLAST FURNACE BUILDING (NOTE ELEVATOR)
9. SUB-STATION
10. ANODE ROLLING MILL
11. SPRAY PONDS
12. TANK HOUSE
13. SLIMES ROASTING
14. GOLD & SILVER BULLION FURNACES
15. GOLD & SILVER ELECTROLYTIC PARTING ROOM
16. COTTRELL TREATER & COOLING TUBES
17. NICKEL PLANT
18. SELENNIUM & TELLURIUM RECOVERY
19. NICKEL SULPHATE BLDG.
20. ADMINISTRATIVE BLDGS.
21. SHOPS
22. BRICK STORAGE
23. OIL STORAGE
24. COPPER AND BRASS ROLLING MILL
25. MAIN CASTING HOUSE
26. SUB-STATION
27. STORAGE AND CATHODE SHEARING

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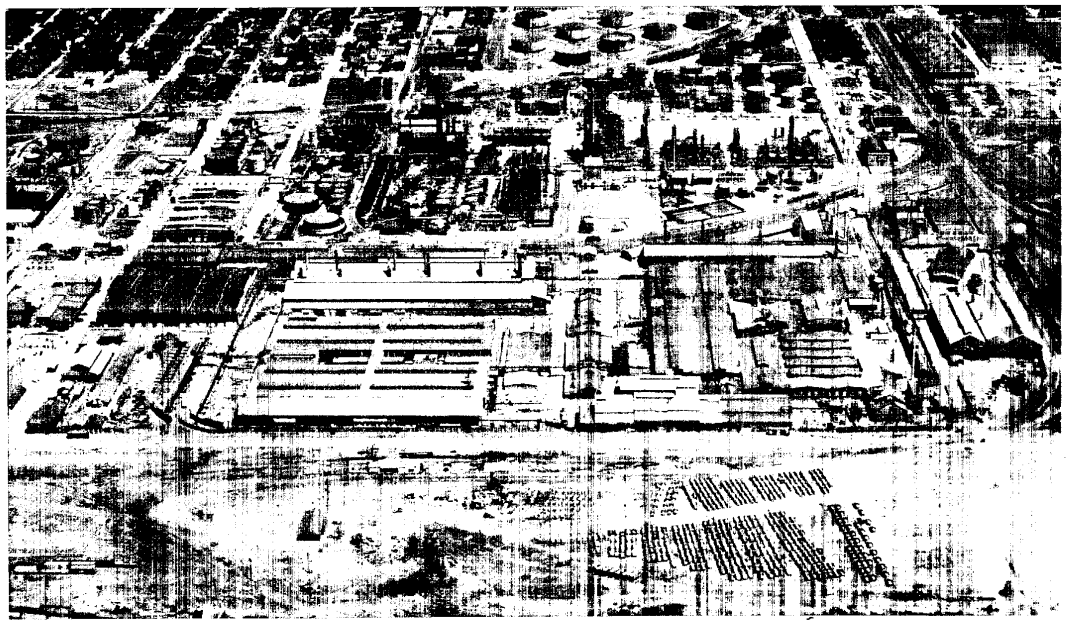
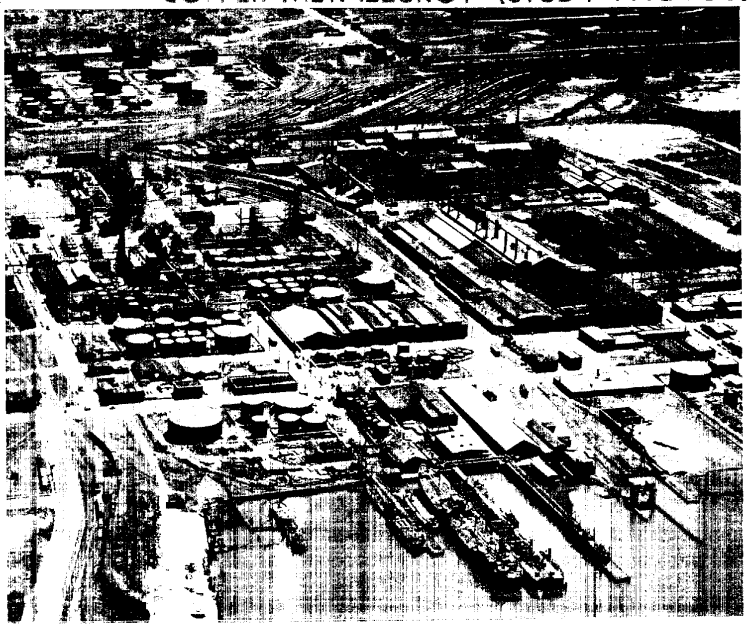
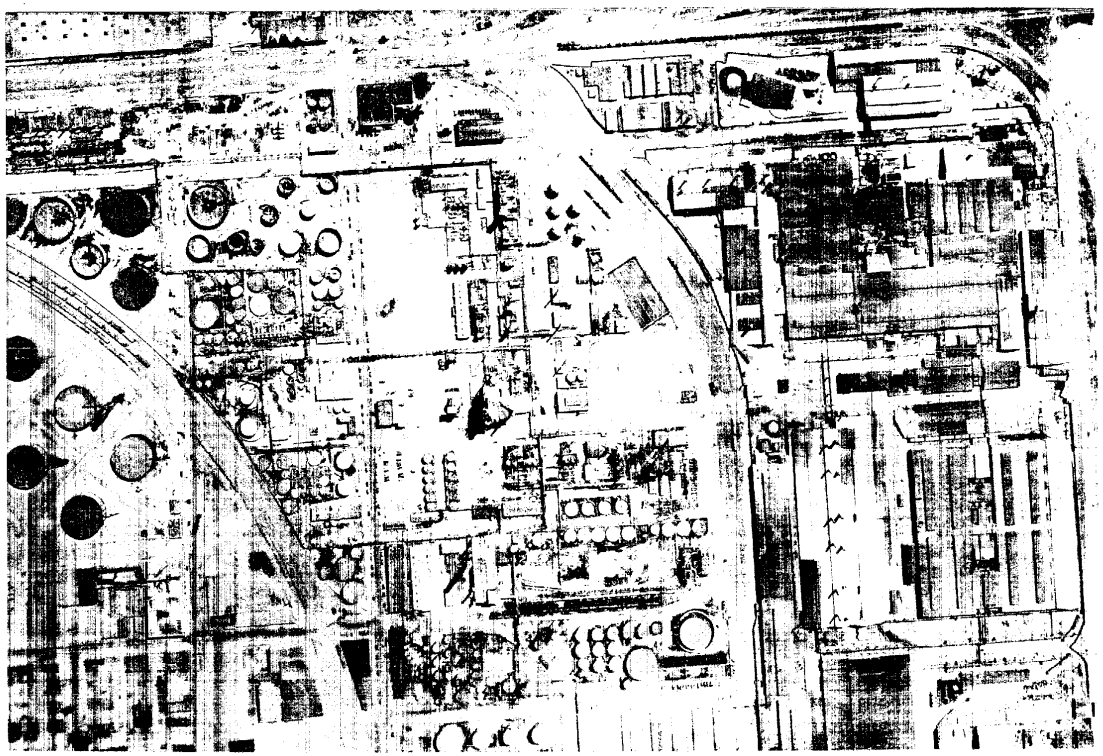
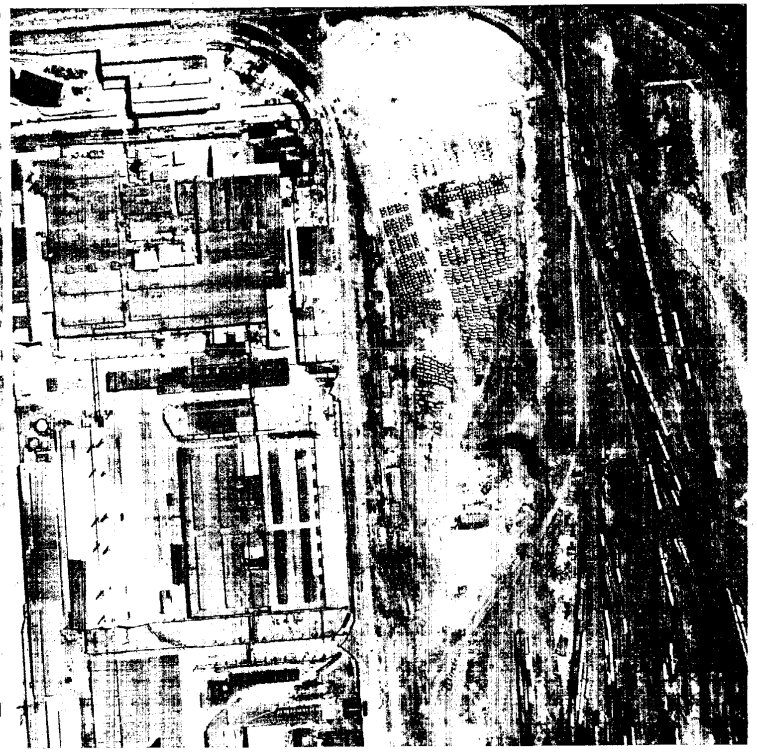




A.S. & R. - BALTIMORE REFINERY - STEREO & OBLIQUE VIEWS





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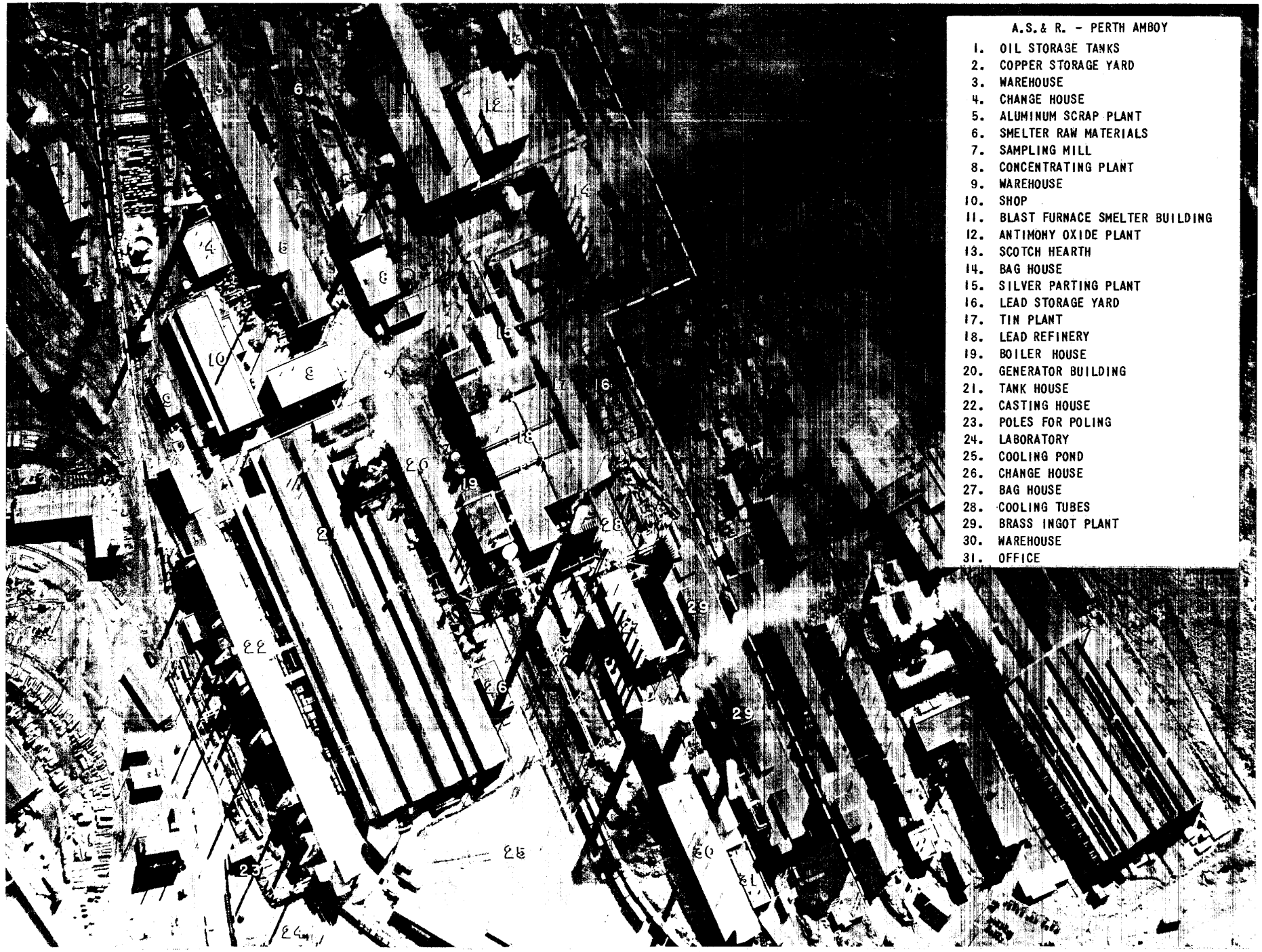

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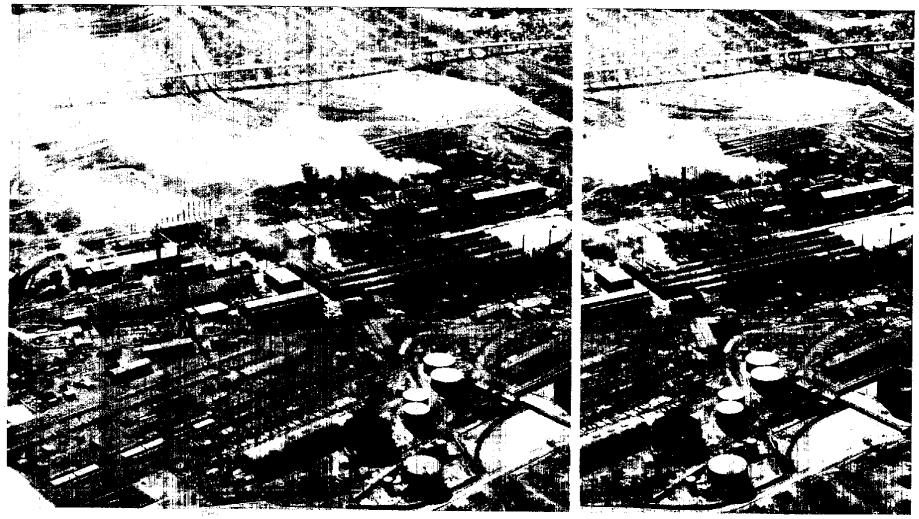
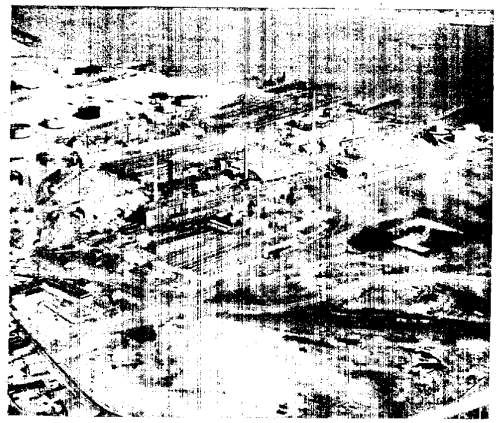
COPPER METALLURGY (STUDY PHOTOS)



A.S. & R. - PERTH AMBOY REFINERY - STEREO & OBLIQUE VIEWS



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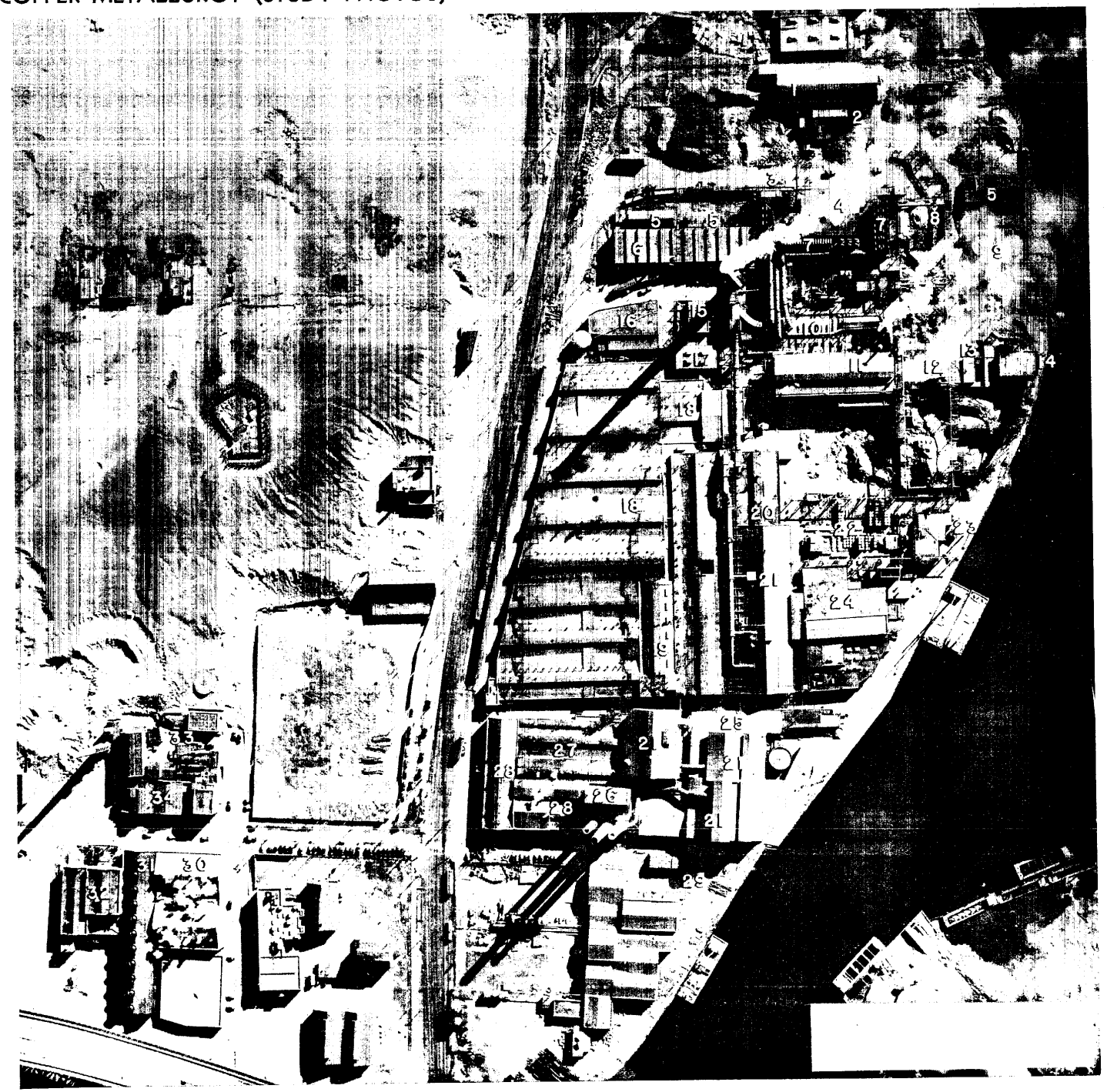
COPPER METALLURGY (STUDY PHOTOS)



1. TIN PLANT
2. OLD TIN FURNACE BLDG.
3. TIN BAG HOUSE
4. SMELTER BAG HOUSE
5. STORAGE
6. MACHINE SHOP
7. COOLING TUBES
8. SMELTER RAW MATERIALS
9. FUEL OIL
10. DUST CHAMBER
11. SMELTER BUILDING
12. SINTER BUILDING
13. CONCENTRATE BIN
14. SAMPLING MILL
15. COTTRELL RECTIFIER HOUSE
16. BRICK STORAGE
17. CHANGE HOUSE
18. TANK HOUSE
19. SLIMES LEACHING
20. RESEARCH LABORATORY
21. CASTING HOUSE
22. STORAGE YARD
23. TESTING BUILDINGS
24. SHIPPING BUILDING
25. INSPECTION BUILDING
26. BOILER HOUSE
27. OLD TANK HOUSE (STORAGE)
28. POWER HOUSE
29. POLES AND BLISTER CAKES
30. COPPER SULPHATE PLANT
31. COPPER SULPHATE EVAPORATION BLDG.
32. NICKEL SULPHATE BLDG.
33. RESEARCH AND LABORATORY BLDGS.
34. COPPER PAINT WORKS

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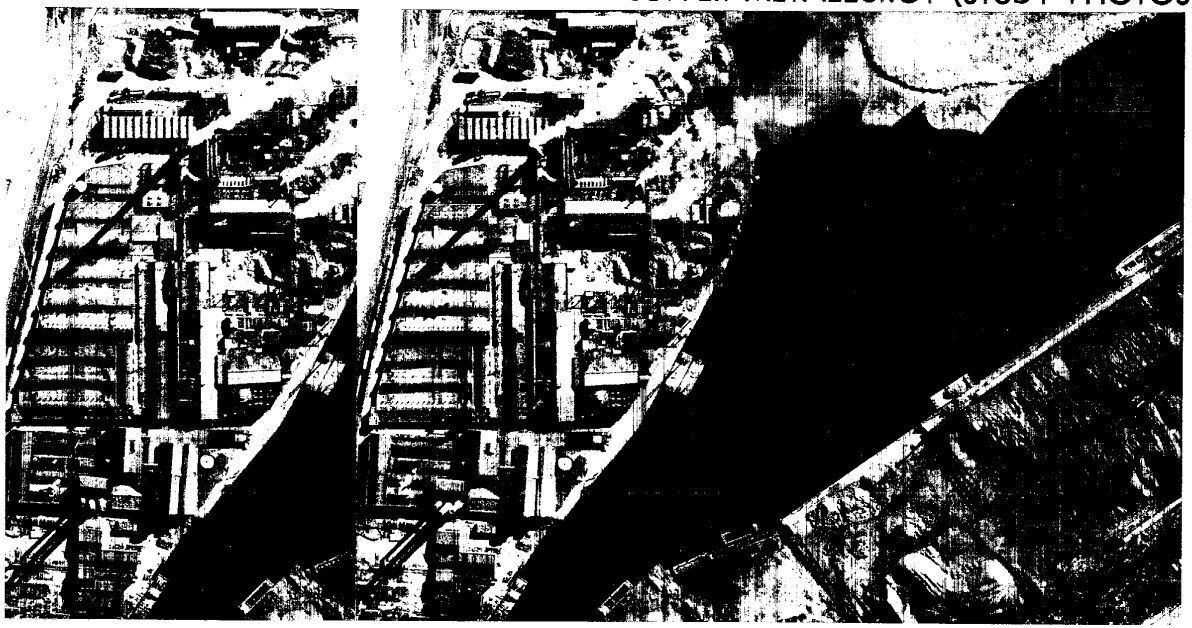
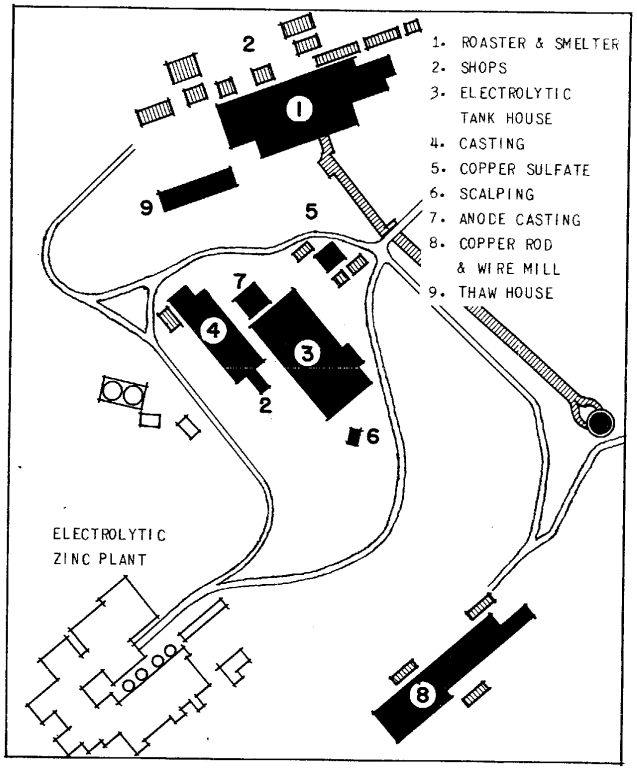
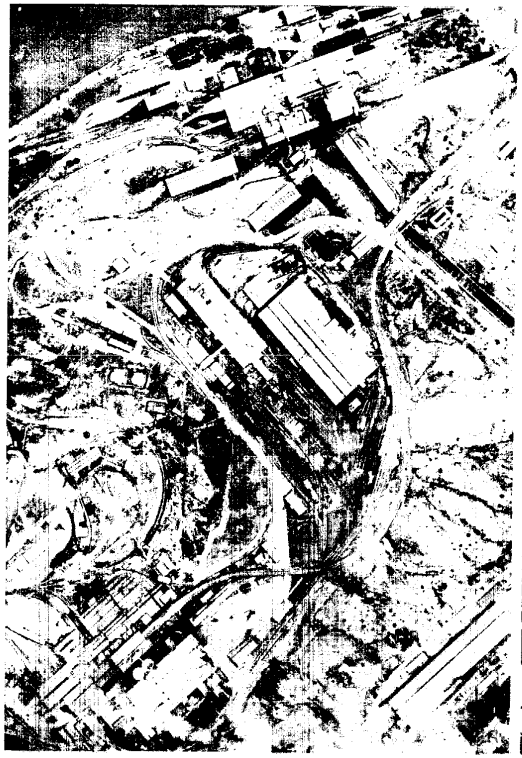
COPPER METALLURGY (STUDY PHOTOS)



ABOVE: PHELPS - DODGE N.Y. REFINERY - STEREO & OBLIQUE VIEWS



BELOW: GREAT FALLS ZINC PLANT & COPPER REFINERY



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COPPER METALLURGY

VULNERABILITY OF SMELTERS AND REFINERIES

VULNERABILITY OF SMELTERS AND REFINERIES

Theoretically, metallurgical plants are better bombing objectives than mining and ore-dressing installations. The same target criteria which showed mining and ore-dressing facilities to be theoretically poor objectives proves the above statement. Thus, copper smelters and refineries are more vulnerable to bombing (1) because fewer plants are responsible for total national production and each is therefore more important, (2) because each plant is larger and presents a larger aiming point, (3) because the time lag between smelting and refining and fabrication is less and cushioning effects therefore fewer, (4) because smelting and refining installations contain more bottlenecks to production, and (5) because smelting and refining equipment is harder to replace.

When a similar comparison of relative vulnerability is made between smelters and refineries, it becomes evident that refineries are better bombing targets because of the first three of the above stated reasons.

In Japanese controlled territory where copper producing facilities consist of approximately 10 refineries, 17 smelters, a score of important ore-dressing mills, and from 75-100 mines, the theoretical approach would seem to apply very well, with refineries representing the number one target. Actually, however, the tightness of Japanese ore supplies and the idleness of much of her smelting and refining capacity complicate the situation greatly. In fact, it might just as readily be proved that the most effective damage in terms of total Japanese copper production loss could be done by destroying five or six dressing mills, with a resultant saving of American planes and bombs. For this reason, and because all types of copper facilities are small as compared with such high priority targets as iron and steel plants, aircraft plants, and shipbuilding yards, in the composite picture of Japan's war production economy, copper facilities probably do not stand high on Allied target lists.

VULNERABILITY OF INDIVIDUAL PLANT UNITS

The long range effectiveness of bomb damage to an industrial plant is determined by the dependence of plant production upon the individual units damaged and by the time required for essential repairs. Time consumed in repairs depends, in turn, upon the construction of the important structures damaged and upon the replaceability of their injured parts.

Production at copper metallurgical plants is dependent upon the following units:

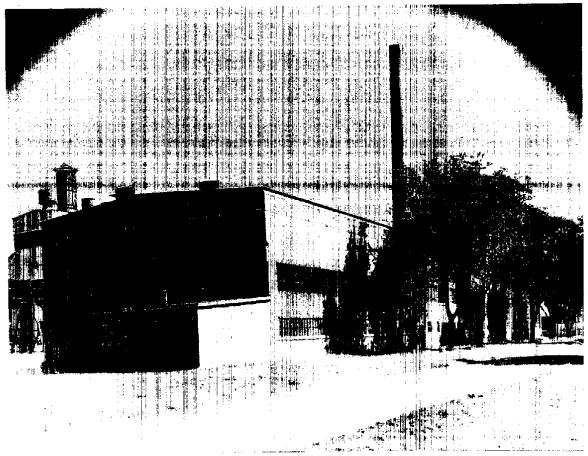
Smelter	Refinery
(1) Powerhouse and air compressor.	(1) Power house or substation
(2) Smelter building.	(2) Tank House.
(3) Roasting or sintering building.	(3) Casting building.
(4) Fuel storage and pulverizing units.	(4) Fuel storage and pulverizing units.

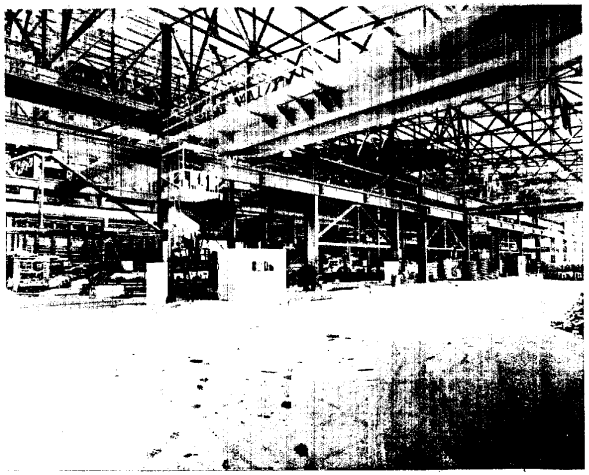
Actually, for efficient and economical production, nearly all units at the smelter are important because each is closely associated with the others. For example, the roasting, smelting, and converting processes are each affected by the chemical constituents of the charges used in the other two, while gas control and dust recovery are important to efficient operation of the entire plant. In fact, serious damage to almost any of the operational parts of a smelter would necessitate drastic changes in production processes in most of the operating parts. Extensive damage to the conveyors, track systems, and rail cars which provide the connecting links between units, although easily repaired, would seriously disrupt smelter operations until repairs could be effected.

Refinery operations at the tank house, the casting house, and the electrolyte purification plant are also interdependent. The tank house is the primary bottleneck.

It should be noted, however, that to be immediately effective damage to roasting and smelting buildings would require knocking out nearly all of the units that operate in parallel. This is also true of the tank and casting houses at the refinery.

NON-INFLAMMABLE AUXILIARY SHOP





INTERIOR OF CASTING BUILDING SHOWING STEEL FRAMING

FIRE VULNERABILITY OF SMELTING AND REFINING BUILDINGS

Copper smelters and refineries may be classed generally as poor incendiary targets because of the non-combustible construction of their buildings and the non-inflammable nature of their contents. The non-combustible construction of sintering, roasting, smelting, casting, and many refinery by-products buildings stems from the fact that each contains furnaces and handles hot materials.

Auxiliary buildings may be of any type of construction, but at most plants they are built of the same materials used for operational structures. Similarly, tank houses at the refinery, although they do not handle hot materials, are predominantly steel framed buildings with non-combustible roofs and brick or stone walls. Wooden cells at some tank houses would probably support combustion, but even these are partially protected by their lead linings and liquid contents.

KEY TARGETS AT THE SMELTER AND REFINERY

Power House and Air Compressor Units

(1) At smelter, power is instrumental to operation of nearly all equipment; compressed air is needed to operate sinter pots, blast furnaces and converters.

(2) At refinery, power is essential to operation of tank house, charging and casting machinery, cranes, pumps, Cottrells, etc.

(3) Importance of power unit varies at each plant with the percentage of electricity brought in from outside sources.

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(4) At refinery, tank house sub-stations contain vital transformers and rectifiers that form an important bottleneck.
(5) Power equipment delicate - would necessitate lengthy repairs if badly damaged.
(6) Air compressors easily injured but standard and not too difficult to replace.

Smelter Building

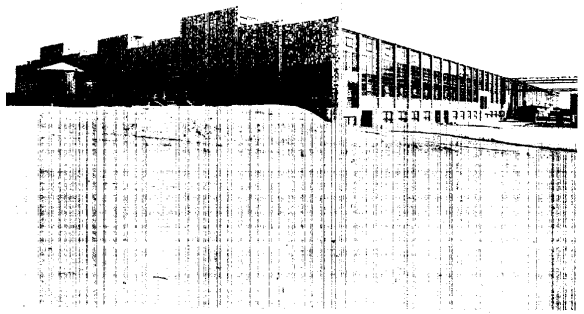
(1) Largest and most important unit at smelter (except where major power unit is located at plant site.)
(2) Contains smelting and converting furnaces in which the most important changes in reduction of copper ores take place.
(3) Blast furnaces too small to be easily hit, but charging mechanism, bustle pipe, and tuyeres highly vulnerable.
(4) Where used, reverbs are the most easily damaged smelter building equipment (a) because of large roof area, (b) because of easily pierced brick construction.
(5) If reverbs operational when pierced, liquid copper would overflow and freeze necessitating tedious repairs.
(6) Waste heat boilers vulnerable, but not essential to plant operations. Might shield reverbs because of position directly under roof.
(7) Converter hoods and turning gear vulnerable to shock and fragmentation; furnace vulnerable only to direct hit.

Roasting or Sintering Building

(1) Because fine concentrates can't be smelted successfully in blast furnaces unless agglomerated, sinter plant vital to efficient blast furnace operation; plant vulnerability varies with equipment - e.g. Dwight-Lloyd machine more easily damaged than pots.
(2) Hearth roaster building essential where preroast needed for reverberatory charges, but building is heavily constructed. Large explosions might tilt roaster hearths out of line from central rotating column causing rabble arms to jam and tear out brick hearth linings.

Tank House

(1) Best target at refinery because of (a) tremendous size, (b) easily damaged contents, and (c) because entire plant is dependent upon its operation.
(2) Interior explosions would damage cells, knock out pipes and pumps for circulation of electrolyte and slimes, and disrupt electrical connections.



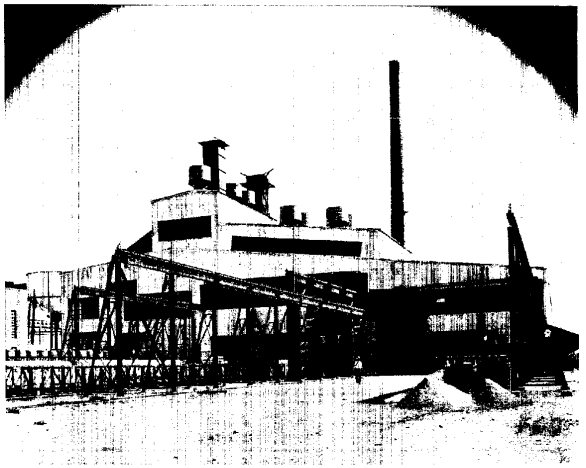
A MODERN ELECTROLYTIC TANK HOUSE

(3) Wood cells easily replaced - concrete cells less so; slight damage to tanks could be isolated by rearranging busbars to by-pass injured cells.
(4) Pumping system biggest bottleneck; pumps hard to replace and circulation of electrolyte, vital to essential purity of cathodes.

Casting Building

(1) Essential equipment includes reverberatory furnaces and casting and charging machines.

CASTING BUILDING SHOWING CORRUGATED IRON PANELING



(2) Casting of high quality shapes must be precisely controlled; precision would be destroyed by shock of adjacent explosions.
(3) Reverberatories and waste heat boilers subject to same damage as smelter reverbs and boilers.
(4) Charging machine contains delicate electric motor.
(5) Casting and charging machines are standard.

Fuel Supply

(1) Oil tanks and pulverizing units are the only highly inflammable refinery units and those are very small.
(2) If no auxiliary fuels available, damage to fuel units might halt operation of vital power plant and air compressor boilers, blast furnaces, and reverbs - all continuous fuel consumers.

Dust Control Equipment

(1) Stacks heavily built and hard to hit.
(2) Flues likely to be hit often in raids, but easily repaired.
(3) Cottrells very small but highly vulnerable.
(4) Crippling damage to dust control equipment would halt by-products plants and make work at smelter inefficient and uncomfortable, but wouldn't halt plant operations.

By-Products Plants

(1) Not essential to smelter and refinery operations.

Auxiliary Buildings

(1) Damage to auxiliary buildings important only for delays in repairs, destruction of office records, etc. that might be caused.

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SECTION 3

LEAD METALLURGY

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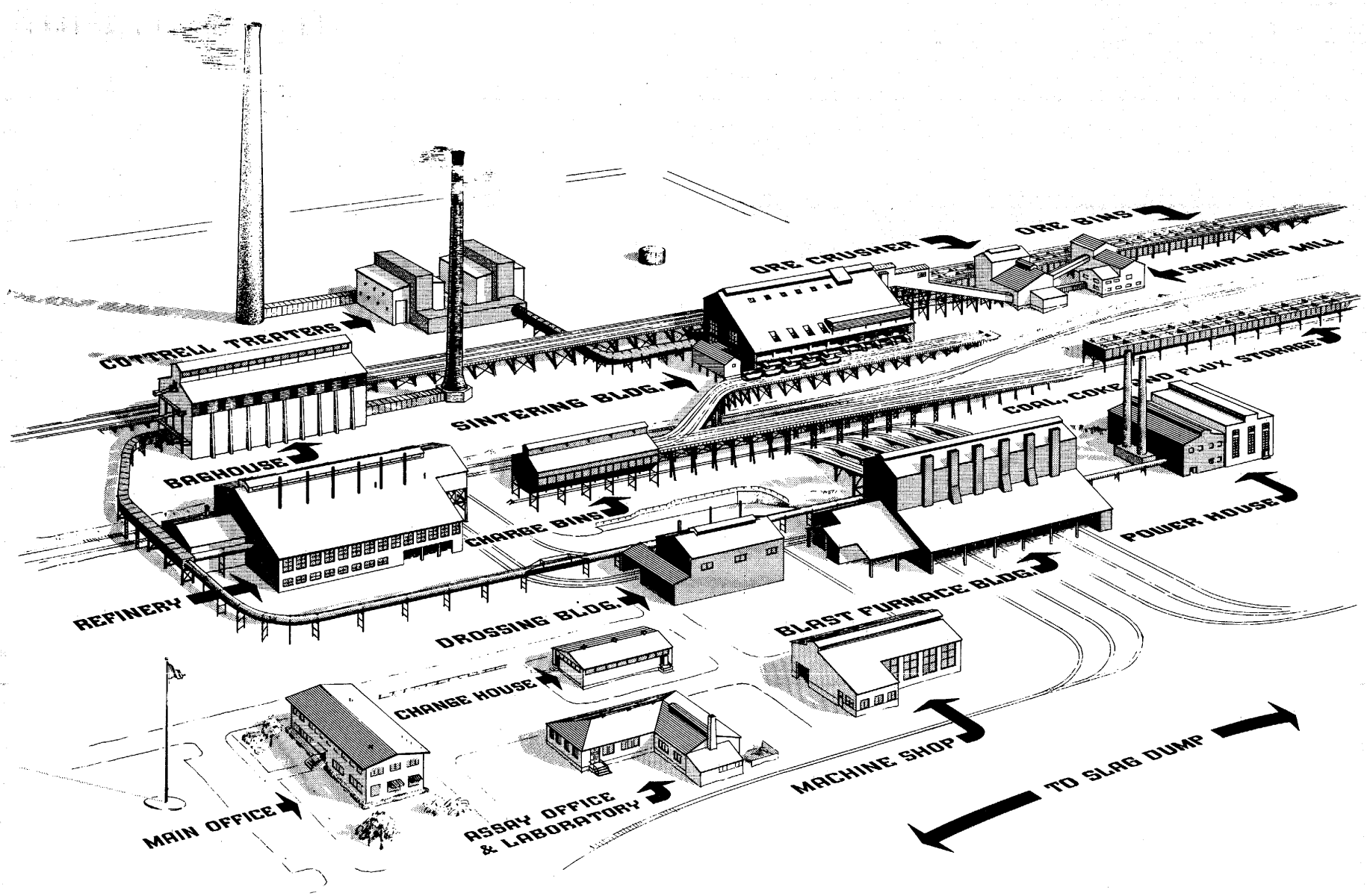
TYPICAL **LEAD SMELTER AND REFINERY**



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LEAD METALLURGY

SMELTING PROCESSES

INTRODUCTION

Lead metallurgical operations are strikingly similar to those of copper, both in the equipment used and in the processes employed. Thus, ores are prepared by roasting and sintering; smelting is carried on predominantly in blast furnaces; refining is accomplished by pyro-metallurgical techniques and sometimes by electrolysis; and casting is done by machinery. As in the copper processes, lead operations divide naturally into extraction and refining departments which are usually considered as separate units. This separation of extraction from refining, however, is less definite than in copper metallurgy because lead smelters often possess facilities for carrying on several, or all, of the essential steps of refining.

Although lead ores and concentrates may be reduced by either pyro-metallurgical or hydro-metallurgical methods, the latter is still largely experimental in the lead industry. Commercial extraction is confined almost exclusively to smelting in carbon heated furnaces.

LEAD SMELTING

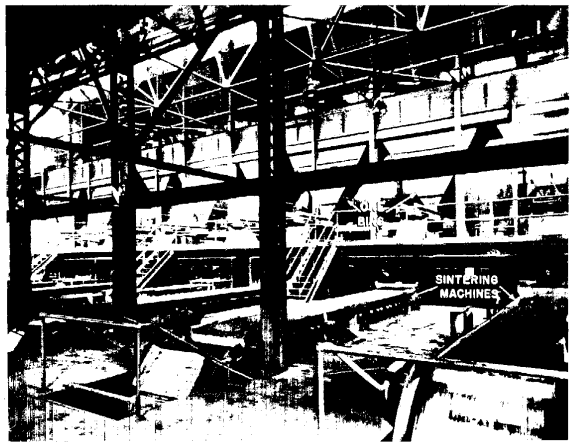
Furnaces used to smelt lead commercially have included reverberatories, blast furnaces, and ore hearths. In recent years, however, reverberatories have been discarded in favor of either blast furnaces or ore-hearths. As a general rule blast furnaces are best suited to the smelting of argentiferous (silver bearing) ores and ore-hearths to the smelting of non-argentiferous ores of high grade, because the majority of ores mined throughout the world are either argentiferous or low grade. Blast furnace smelting predominates in the lead industry. This is especially true in Japan where lead ores are both argentiferous and low grade.

SINTERING AND ROASTING

Regardless of the method used and the ore smelted, sulfur must first be burned off, at least in part, and the other impurities must be combined in a slag. In blast furnace smelting, sulphur is usually eliminated from the ores by sintering in the same manner and with the same types of equipment used for preparing copper blast furnace charges. To eliminate the required amount of sulphur several sinters are necessary. Some plants obviate additional sinters by giving the ore a preliminary roast in a multiple hearth furnace or in stages as all their roasting in hearth furnaces.

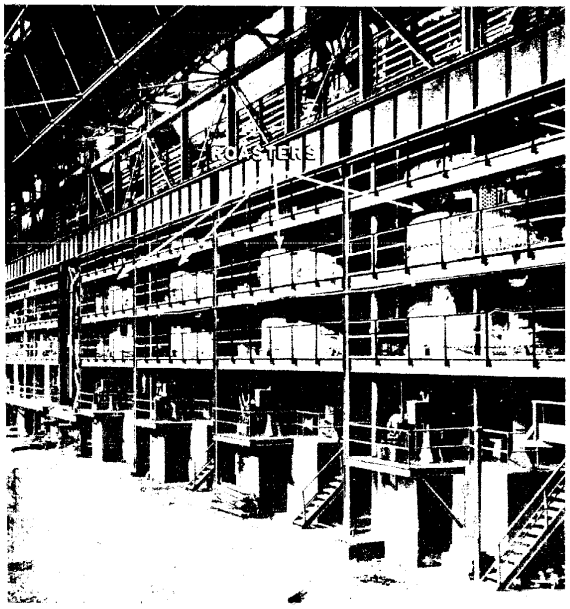
SMELTING IN THE BLAST FURNACE

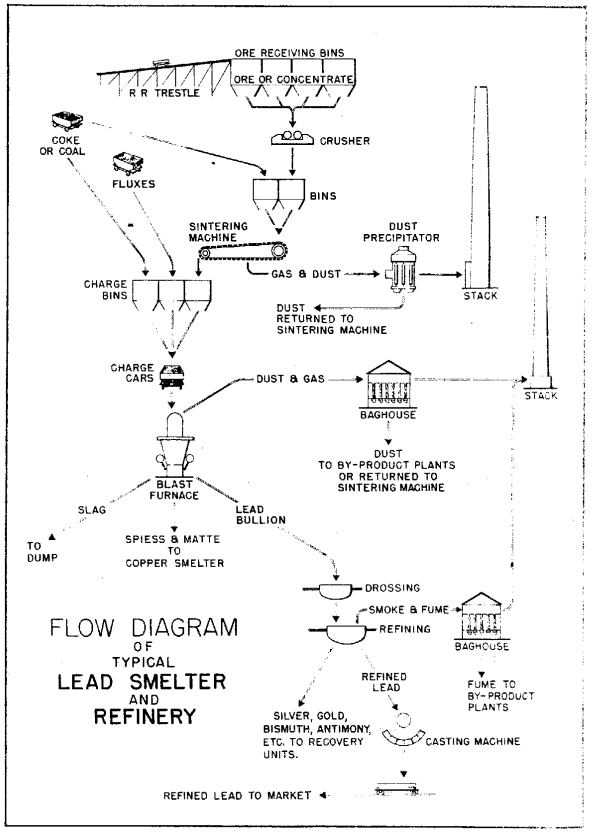
After elimination of sulphur, the resulting sinter calcine is ready for smelting in the blast furnace. The function of the blast furnace is to free the metal from the ore and to gather the impurities in a slag. This separation is effected by the differences in specific



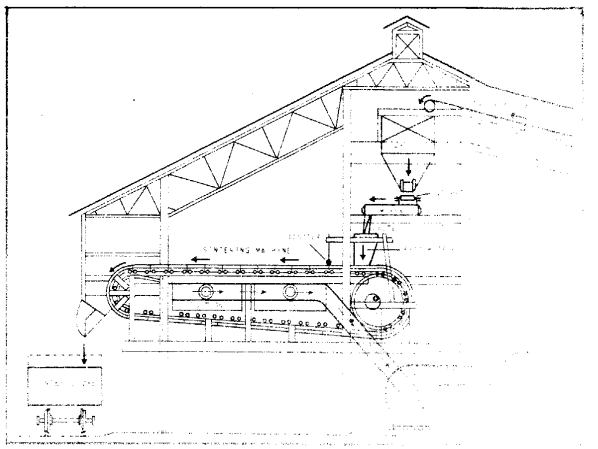
ABOVE: INTERIOR OF SINTERING BUILDING

BELOW: INTERIOR OF ROASTING BUILDING





SECTION THRU DWIGHT-LLOYD SINTERING BUILDING



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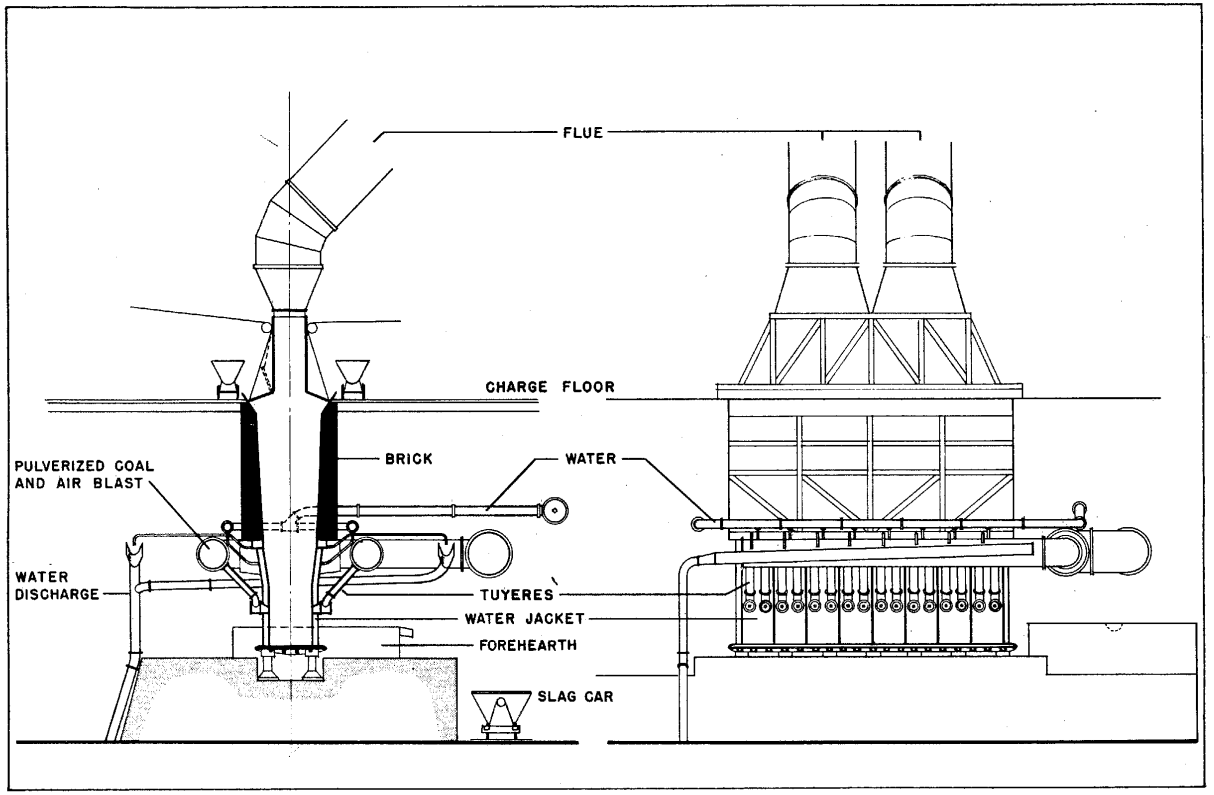
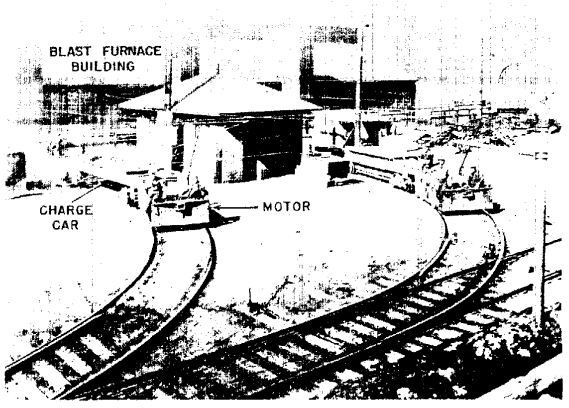


SECTION & ELEVATION THROUGH BLAST FURNACE

CHARGE CARS AT REAR OF BLAST FURNACE BUILDING



DROSSING LEAD BULLION

gravity of the various liquids produced, which include molten lead bullion, a ferro-arsenide speiss, a copper - iron - sulphur matte, and a ferro-silicate slag. Inasmuch as liquid lead is the heaviest, it forms at the bottom of the furnace and is topped by a speiss, matte, and slag in ascending order. In commercial practice lead bullion and slag are most important for matte and speiss form in only small quantities.

Furnace Operations: The lead blast furnace is almost identical with the copper blast furnace both in its construction and in the general principles of its operations. It possesses the same rectangular horizontal section, tapered sides, compressed air bustle pipe, water jacketed smelting zone, and the same row of tuyeres that feed compressed air to the charge column from the bustle pipe. The sole difference is in size; lead blast furnaces are seldom longer than 25 feet.

The furnace charge consists of sintered or roasted ore, silica and iron fluxes, and coke. At some plants a portion of the coke in the charge is occasionally supplemented with powdered coal blown through the tuyeres. As the charge fuses and settles in the furnace column, the various liquids formed seep downward to a crucible at the furnace bottom. Lead bullion is tapped directly from this crucible but speiss, matte, and slag are drawn off into a forehearth where they are allowed to settle into more clearly defined layers before tapping.

Treatment of Blast Furnace Products: The crude lead bullion as tapped from the blast furnace is transferred to a drossing kettle or to a small reverberatory furnace where it is freed from some of the impurities held in suspension or solution. This is accomplished by mechanical stirring of the liquid with compressed air or steam. The impurities which include primarily copper and sulphur, rise to the surface of the bath and are removed as a dross by skimming with a perforated disc or huge spoon. The dross thus skimmed is usually returned to the blast furnace after first being freed of its occluded lead by settling in a reverberatory furnace or by pressing. After removal of drosses, the cleaned lead bullion is cast into pigs (if refining equipment is not present at the smelter) and shipped to the refinery.

In the blast furnace forehearth matte and speiss are allowed to accumulate, while the slag is tapped into slag pots and hauled away to a dump. At some plants part of the slag is granulated and mixed as a diluent with the ore charges of sintering machines in order to keep the sinter calcine from fusing. At other plants where the slag is high in zinc it is treated in rotary kilns to recover the zinc as oxide.

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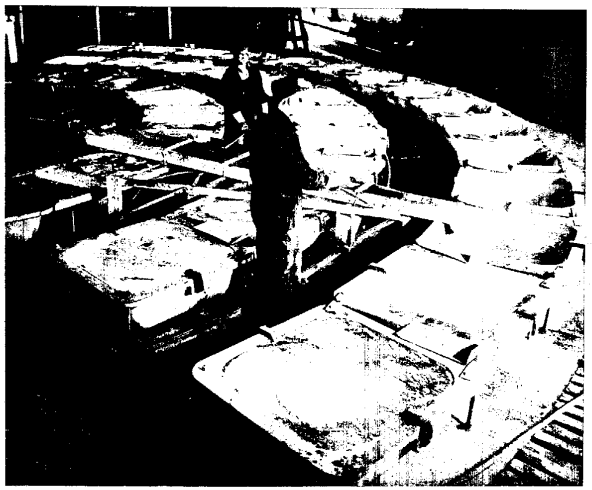


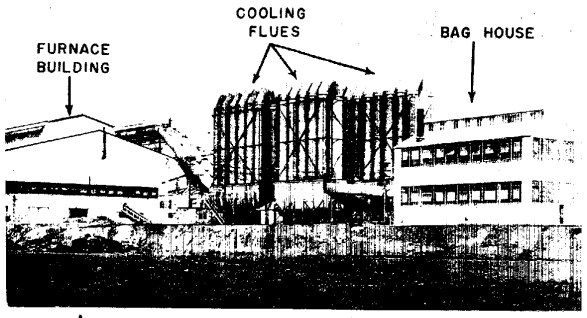
CASTING LEAD BULLION INTO 4-TON PIGS

DUMPING MOLTEN SLAG

As the matte and speiss build up in the forehearth they are tapped together and allowed to freeze preparatory to retreatment. Matte contains valuable amounts of silver, gold, lead, and copper which cannot be wasted. If the quantity of matte is small, it is crushed, mixed with sinter charges to remove sulphur, and returned to the lead blast furnaces. Where the amount of matte is larger, it may be matte-smelted and concentrated in a copper blast furnace for sale to copper smelters.

Before the matte is crushed or retreated the small amount of speiss associated with it is broken off and sent to the arsenic recovery plant where it is processed about the same as arsenic fume. The speiss residue remaining in arsenic roasters after arsenic has been volatilized is sold to copper smelters for recovery of copper and other metals.

Fume and Dust Control: The gases, dust, and fume from lead sintering machines and blast furnaces are carefully controlled and retreated just as at the copper smelter. Hoods are placed wherever fumes arise around the blast furnace with pipes from all hoods leading to a main flue and exhaust fan which connect in turn through expansion chambers and/or cooling flues to a bag house or Cottrell plant. Bag houses are much more common at lead smelters than they are at copper smelters principally because lead smelter smokes are less acidic. If



DUST RECOVERY SYSTEM

the market and the composition of the ore warrant it, sulphuric acid, arsenic, and cadmium plants may be associated with the "dust" recovery system.

Summary: In summary it may be said of the lead blast furnace that it is the objective point on which turns the entire transportation system and flow sheet of the smelter. The receiving and disposal of raw materials (fluxes, fuels, and ores) for the furnace, and the disposal of its waste, intermediate, and primary products form part of the general arrangement of the whole smelting plant, involving also the sampling and storing of materials, the roasting and preparation of smelting charges, and the disposition of power, water, and other necessary factors.

SMELTING IN THE ORE HEARTH

The use of ore hearths is restricted to ores that have a lead content of at least 65%, that are low in silica and that contain no silver. Since there are only a limited number of ore deposits with these characteristics it is doubtful if Japanese smelters employ ore hearths in preference to blast furnaces. Where suitable ores are available ore hearths may be installed if coal is scarce and labor cheap. Other advantages of this type of furnace are that it's initial cost is less than that of a blast furnace and that the ore requires no roasting or sintering prior to smelting.

An ore hearth is essentially a low fireplace surrounded by three walls with one or more tuyeres at the back through which a light blast of air is forced. In the front there is a pot into which the molten lead is run. Over the hearth is an iron hood, leading into a

INTERIOR OF HEARTH FURNACE BUILDING

flue, through which a fan draws the fumes and gases and forces them into a baghouse. The hearth may be either water or air-cooled.

The charge is a mixture of rich sulfide ore, coal or coke, and usually some lime. Reduction of the ore is accomplished not only by the reactions taking place between lead oxides, sulfides, and sulfates but also by the reducing action of the fuel. The molten lead collects in the bottom of the hearth and flows into the pot in front of the furnace. The slag is raked off periodically and since it contains 30 to 40% of lead it, together with the dust collected in the baghouses, is sent to blast furnaces for further smelting.

The molten lead accumulated in the ore hearth pots is collected and transferred to a drossing kettle or small reverberatory furnace where the impurities are skimmed off. Following drossing the lead is cast into commercial shapes and shipped to consumers or refineries, although ordinarily ore hearth lead does not require further refining inasmuch as it contains no silver.

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LEAD METALLURGY

REFINING PROCESSES

LEAD REFINING

A refining plant has for its task not only the separation of gold, silver, and other precious metals from lead, but also the removal of the impurities copper, tin, bismuth, arsenic, antimony, sulfur, etc., and the consequent concentration of a bullion carrying 95 to 98 percent lead to a refined lead of not less than 99.9 percent purity. The impurities themselves must also be worked up into salable products.

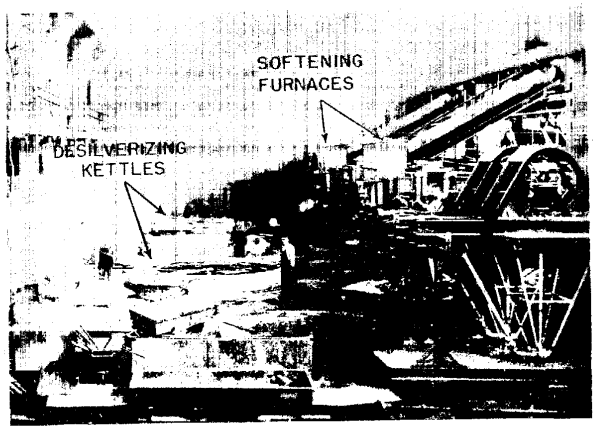
There are three standard methods of refining lead: the Pattinson process, the Parkes process, and the Betts electrolytic process. Any one of these may be used, although, the Parkes method is by far the most widely employed. Desilverization by either the Parkes or Pattinson process is preceded by an operation known as "softening" and is followed by "cupellation"; electrolytic refining requires neither softening nor cupellation.

The three refining processes and their associated operations are discussed below.

SOFTENING

Lead arriving at the refinery, after having been subjected to a preliminary drossing at the smelter, still contains numerous impurities which must be removed prior to desilverization. The lead pigs are mechanically charged into water jacketed reverberatory furnaces where they are very slowly melted down and well stirred. The initial skimming of the molten metal removes most of the copper which rises to the surface as a pasty dross consisting of a mixture of copper, lead, sulfur, arsenic,

INTERIOR OF REFINERY



etc. During the second and third stages, the temperature is increased and the metal is freely exposed to the air. Tin, antimony, and the remainder of the other metals are oxidized and periodically skimmed off.

After softening, the lead is either cast into molds or is tapped directly from the softening furnace into the desilverizing pans or kettles.

DESILVERIZATION

Desilverization, or the extraction of silver from the softened lead, may be accomplished by either the Parkes or Pattinson process or by modifications of these two processes.

Pattinson Process. The Pattinson process is based on the fact that when molten lead is slowly cooled, the crystals which form contain less silver than the remainder of the lead which remains fluid. Successive crystallizations of the softened bullion yield marketable lead plus a small amount of silver-rich lead that is further treated by cupelling to obtain silver.

The Pattinson process is conducted in a series of cast-iron pots or "kettles," eight to sixteen in number, which average about 5 ft. in diameter and 3 ft. in depth. After a sufficient number of heatings and coolings the crystalline lead is removed by a perforated ladle, remelted, and cast into commercial shapes. The residual molten metal is treated for the recovery of silver.

Parkes process. The Parkes process utilizes the greater affinity of gold and silver for zinc than for lead and the insolubility of the zinc-gold and zinc-silver alloys in molten lead.

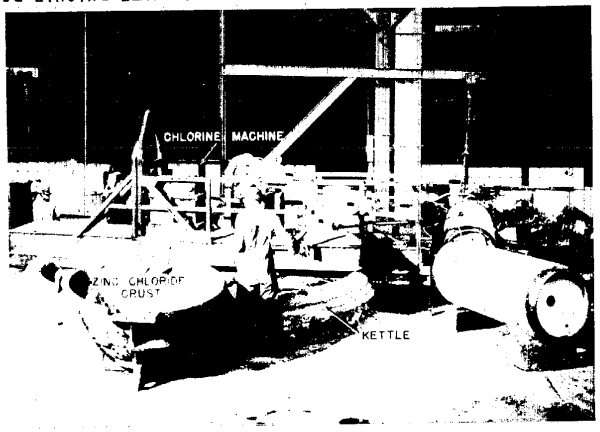
The desilverizing process is carried out in large cast iron kettles or pots, similar to, although larger than those employed in the Pattinson process. Molten bullion from the softening furnace is run into the kettles and just enough zinc is added to combine with the gold. A zinc-gold alloy is formed which rises to the surface as a crust when the temperature of the bullion is slightly lowered. This zinc-gold crust is collected by a mechanical skimmer or manually with a perforated ladle. The lead is now heated again, zinc is added, and the crusts which form on cooling are removed in the same way as the gold-rich crusts. These second crusts will contain by far the greater part of the silver which was present, however, an additional zincing and skimming are usually given the lead to collect any silver which might have remained.

SKIMMING OFF GOLD AND SILVER CRUSTS

The gold and silver-rich crusts, consisting primarily of silver, gold, lead, and zinc are broken up while still hot and charged into a retort furnace in which the zinc is distilled off. The residue remaining in the retort is a mixture of silver, gold, and lead which is further treated in a cupelling furnace to eliminate the lead.

The desilverized lead after all silver and gold has been removed, will contain a small percentage of zinc which must be removed prior to its casting into commercial shapes for the market. In this operation, the lead is run from the desilverizing kettle in a reverberatory furnace where the molten lead is heated to redness with a free admission of air. Two or three skimmings remove all zinc, the lead being allowed to cool before each skim-

DE-ZINCING LEAD WITH CHLORINE MACHINE



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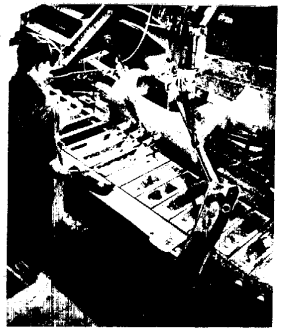


FILLING END CASTING MACHINE DISCHARGE END

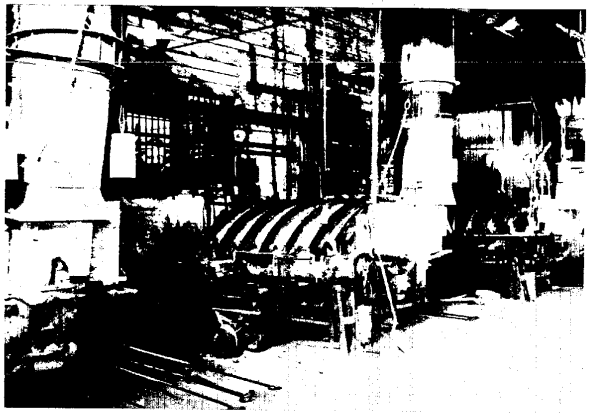
ming. While this is the method most commonly employed for zinc removal, some plants pump the lead through a closed cylinder filled with chlorine and remove the zinc in the form of zinc chloride. The purified lead is now run into a "market" kettle where it is slightly cooled before being poured into the moulds of a casting machine. Upon cooling the refined lead is weighed, inspected, and shipped to consumers.

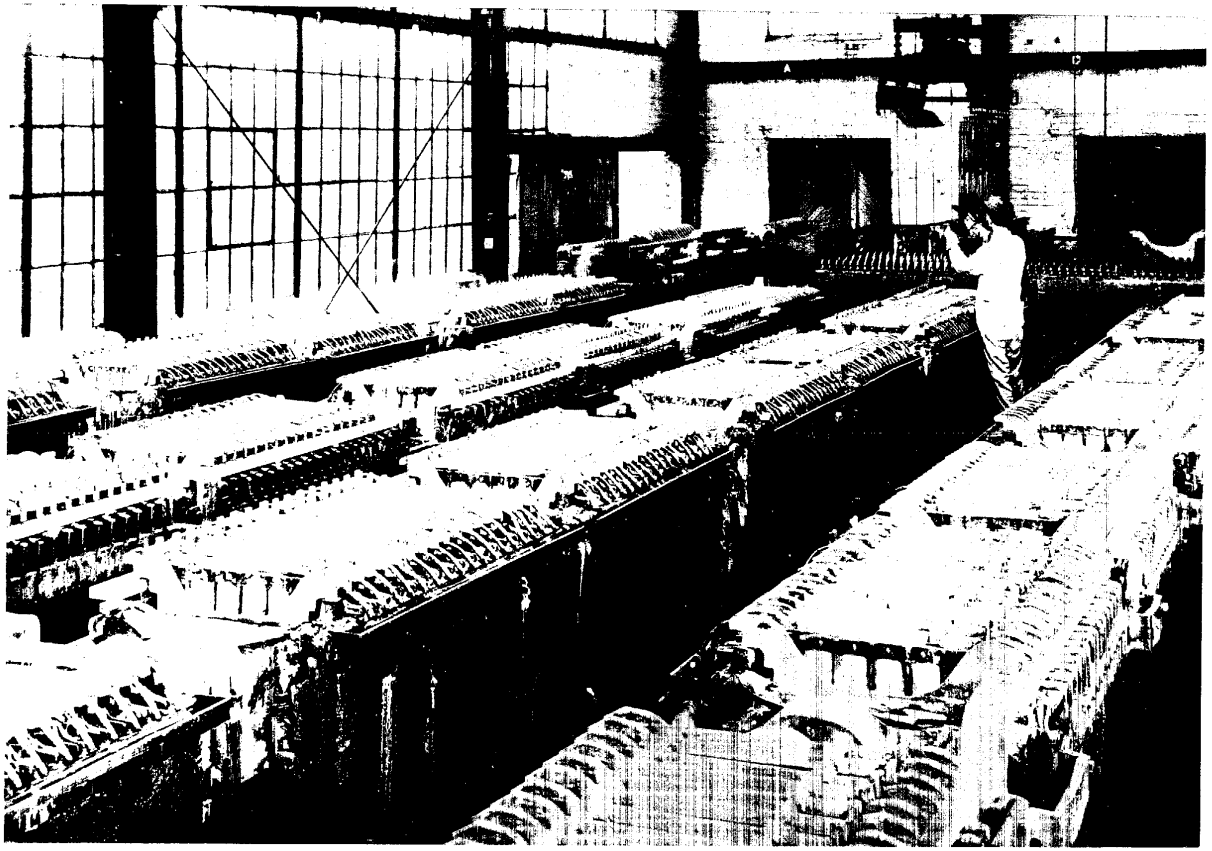
CUPELLATION

Silver and gold, if present, are recovered from the residual molten metal left in the Pattinson process and the skimmings produced by the Parkes process by a method known as "cupellation."

The purpose of cupellation is to oxidize the lead and all other metals present with the exception of the gold and silver. This is effected by heating the bullion to a bright red heat in a small reverberatory furnace. A

CUPEL FURNACES





ELECTROLYTIC CELL ROOM

blast of air is played on the surface, oxidizing the lead to PbO which floats as a liquid on the surface of the molten gold and silver. When all the lead and foreign metals have been oxidized and removed, the gold-silver alloy is cast into anodes for subsequent electrolytic parting.

ELECTROLYTIC REFINING OF LEAD

A very pure metallic lead is obtained by refining the base blast furnace bullion by means of the Betts electrolytic process. The electrolysis is carried out in hundreds of vats or cells which usually are constructed of wood with an internal coating of asphalt. These vats, approximately 7 ft. long, 3 ft. wide and 4 ft. deep, each contain 20 to 30 base lead anodes and the same number of thin pure lead cathodes.

Base bullion arriving from the smelter is melted and cast into one inch thick anodes, 3 ft. in length and 2 ft. in width. These are placed in the vats and immersed in the electrolyte, (a solution of hydrofluosilicic acid and lead fluosilicate). The application of current during electrolysis transfers the lead from the anodes to the cathodes, leaving the foreign metals clinging to the anodes as a sludge which is periodically brushed off. The sludge, containing gold, silver, copper, arsenic and antimony, is collected from the bottoms of the vats, washed, dried, melted, and cast into bars which are subsequently parted with sulphuric acid.

Upon completion of the electrolysis practically all of the lead is transferred from the anodes to the cathodes. The pure lead cathodes are withdrawn from the cells, melted, and cast into the desired market shape.

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LEAD METALLURGY

REFINING PROCESSES

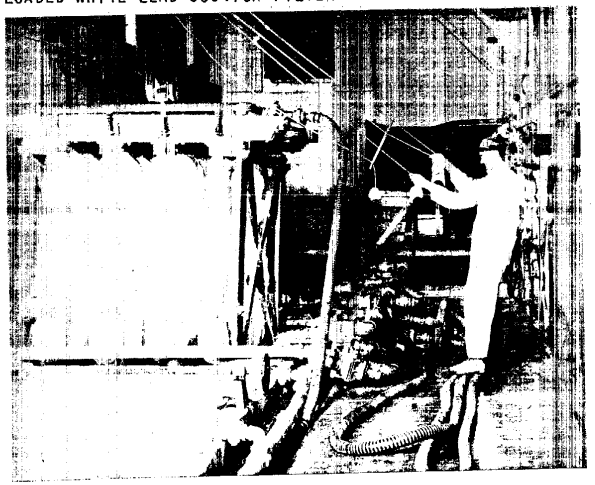
THE MANUFACTURE OF WHITE LEAD

In addition to silver, gold, tellurium, bismuth and antimony recovery units, many lead refineries also manufacture the pigment white lead. The presence of white lead plants at refineries and not at smelters is explained by the fact that a very pure lead must be used in the process.

The type of equipment employed in manufacture of white lead depends on the individual producer since there are a number of different processes from which to choose, but all processes, with the exception of the electrolytic, are alike in that the raw materials required are: (1) atomized lead or cast shapes with a maximum surface area; (2) acetic acid, and (3) carbon dioxide. The acetic acid acts as a corroding catalyst, assisting the carbon dioxide in the conversion of lead to white lead, ($2PbCO_3Pb(OH)_2$). This product is filtered, ground, screened and either packed and sold as dry white lead or mixed with linseed oil and sold as white lead in oil.

While most of the world's white lead is produced by the older corrosion methods, the manufacture of this pigment by electrolysis is increasing. Electrolytic white lead is produced in electrolytic cells of the same general type as are used in electrolytic metal refineries. Simultaneous with the dissolution of the lead anodes, white lead is formed in the cell and is carried by the circulating solution to settlers. The settled white lead is filtered, washed, dried, ground, and then barreled.

LOADED WHITE LEAD SUCTION FILTER



Sublimed white lead. Another paint pigment, $2PbSO_4 \cdot PbO$, commercially called "basic sulfate white lead", or "sublimed white lead", is also often manufactured at lead smelters and refineries. One process involves the spraying of molten lead into a special furnace, where it is acted upon by ignited fuel gas, air, and sulfur dioxide. The basic lead is formed in the furnace as a fine dust which is drawn off through cooling flues and collected in baghouses, cottrells, or other dust precipitating systems. Sublimed white lead is also produced by subjecting selected lead sulfide ores to a high temperature in an oxidizing atmosphere. A third process treats finely divided metallic lead with water and sulfuric acid to form a basic sulfate white lead precipitate.

DISTINGUISHING FEATURES OF SMELTERS AND REFINERIES

The similarity between copper and lead smelting operations is conspicuously reflected in the layout and general external appearance of the two plants. Not only are the outstanding features of copper smelters such as the tall stacks, the long winding flues, the ore piles and bins, and the large black slag piles duplicated at lead smelters, but the similarity even extends down to the individual plant units. The technical requirements of both metallurgical processes call for: facilities for the storage, crushing, and mixing of ore and other raw materials making up the furnace charge: roasting and/or sintering equipment; smelting furnaces; and numerous auxiliary units such as power plants, offices, laboratories, shops, warehouses, and by-product plants.

The major difference between the two plants lies in their relative size; copper facilities being much larger than their lead counterparts. Another difference exists in the type of dust precipitation equipment; copper smelter gases are generally passed through Cottrell treaters, which are small in size, while the gases from lead smelting furnaces are usually filtered in large bag houses. Other minor differences which might be noted are the lack of converters and the relatively larger sintering and roasting buildings at lead smelters.

The similarity of copper and lead metallurgical plants ends at the smelters and does not carry through to their respective refining units. Lead is usually refined by simple pyro-metallurgical methods, whereas, copper is commonly subjected to fire refining, followed by electrolysis. Where lead refineries exist as separate plants, the problem of identifying them is exceedingly difficult since they lack tall stacks, slag piles, and other distinctive features, however, in most cases refineries are built as an integral part of smelters.

Listed below are the external characteristics of each of the major buildings comprising a smelter and a refinery, together with such other recognition clues as the building's position, its associated stockpiles, and its rail, pipeline, and conveyor connections.

DISTINGUISHING FEATURES OF SMELTER BUILDINGS.

Ore Bins

Long line of bins beneath railroad tracks.

Ore cars dump ore, coal, coke and fluxes into bins for storage prior to their consumption.

Ore bins connected to crushing plant and mixing building by tracks or conveyor system.

Crushing Plant

Medium sized building with composite roof structure.

At least one tower-like structure to house ore hoisting equipment.

Located near ore bins.

Conveyors or larry cars transport crushed ore to sintering building.

Building Contents: Crushers, grinders, screens, mixers, and ore bins.

Sampling Mill

Medium sized building similar in appearance to and associated with crushing plant.

Connected to ore bins by tracks or conveyors.

Function of the mill is to test and crush ore, concentrates and fluxes.

Roaster Building

Size and shape depends on the type of roasting furnace installed - usually a fairly high gable roof building.

Large flues carry roaster gases and dust to tall stack, via a dust recovery system.

Larry cars convey roasted ore to sintering plant or to charge shed.

Building contents: Roasting furnaces, ore hoist-

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ing equipment and ore bins.

Note: This building not always present. Roasters may be included in sintering building or roasting may not be employed.

Sintering Building

Fairly large building with gable roof - one of the highest buildings at the smelter.

Large flues carry gases to dust precipitating units and thence to a tall stack.

Larry cars take sintered ore to charge shed.

Building contents: Sintering machines, suction fans, ore bins and sometimes roasters.

Charge Shed

Small structure - height and roof construction variable.

Correct proportions of sintered ore, coke, coal and fluxes are discharged from bins into the blast furnace charge cars.

Tracks connecting charge shed and smelting building usually visible.

Building contents: Ore bins and sometimes crushers and screens.

Smelting Building (Blast Furnace)

Largest and usually the highest structure at the smelter.

Gable roof building with shed extension.

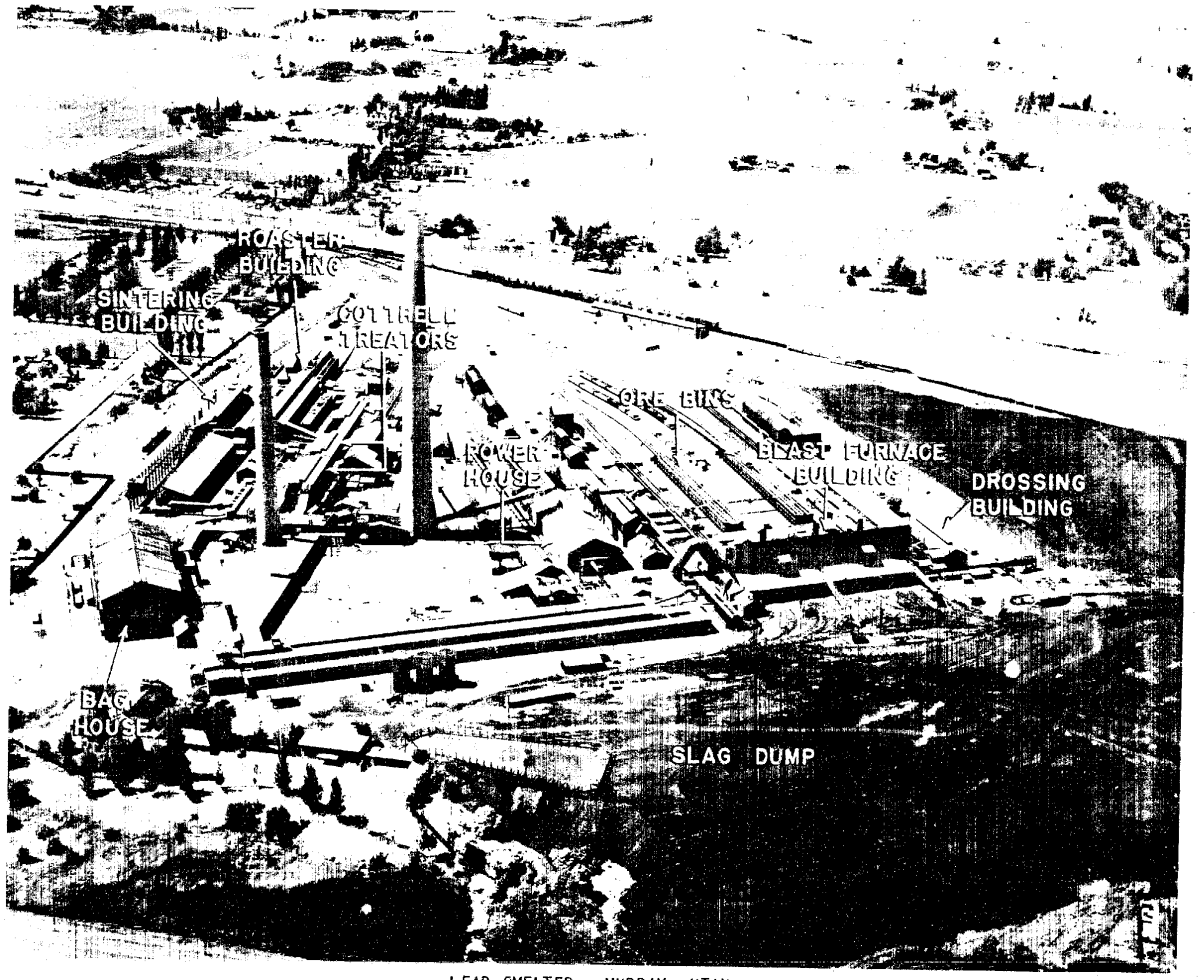
Normally 4 or 5 short stacks.

Large flues carry blast furnace combustion gases via baghouse to tall stack.

Compressed air pipe enters furnace building from power or compressor plant.

Conspicuous pattern made by tracks leading to slag dump.

Building contents: Blast furnaces and sometimes drossing furnaces and casting wheels.



LEAD SMELTER - MURRAY, UTAH

Smelting Building (Ore hearths)

Longer and narrower than a blast furnace smelting building.

Moderately high gable roof structure with continuous monitor.

Large flue transports furnace gases from building through baghouse and then to stack.

Compressed air pipe enters furnace building from power or compressor plant.

Slag is transported to small blast furnace building for further smelting before discarding.

Crude lead produced by the ore hearths is moved to the drossing and casting building.

Note: Japanese probably do not use ore hearths since their ores can be more efficiently smelted in blast furnaces. Where ore hearths are employed, roasting and sintering are not required prior to smelting.

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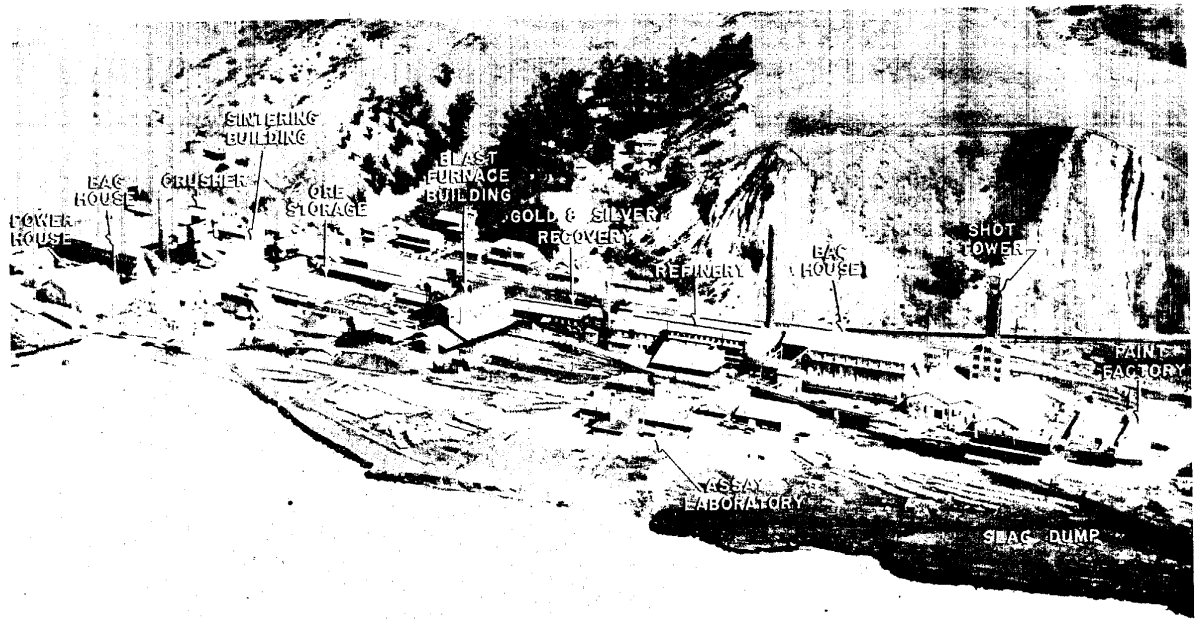
LEAD METALLURGY

DISTINGUISHING FEATURES OF SMELTERS AND REFINERIES



LEAD SMELTER AND REFINERY - SELBY, CALIFORNIA

Drossing and Casting Building

Located near and sometimes adjoins smelting building.

Relatively small building of moderate height, - nearly square in plan.

Continuous monitor and usually several short stacks.

Drossed lead is cast into pigs and sent to a refinery which may or may not be at the smelter site.

Building contents: Drossing kettles or small reverberatories, crust skimming equipment, and casting wheels.

Baghouses

Long buildings of moderate width and height.

Usually low pitch gable roofs.

Easily identified by the large flues which enter and exit from them and by their proximity to the tall stack.

Building contents: Large cotton or woolen bags which filter the blast furnace and drossing furnace gases.

Cottrell Treaters

Smaller and lower than baghouses.

Large flues which enter and exit from Cottrells provide recognition feature.

Cottrells treat roaster and sintering machine gases while baghouses treat blast furnace gases.

Usually located near tall stack.

Building contents: Rectifiers, transformers, and electrically charged wires or pipes.

Power plant

Medium sized heavily constructed building.

Usually in two sections - a gable roofed boiler section and a turbine and generator section which has a flat or low-pitch gable roof.

Identified by the tall, relatively thin stacks - normally 1 to 3 in number.

Coal piles, spray ponds, and/or cooling towers generally alongside power plant.

Sometimes outdoor transformer yard noted.

Building contents: Boilers, turbines, generators and often air compressors.

Auxiliary Buildings

Offices can be identified by their position, size and shape, parking lot and entrances.

Warehouses are usually large low structures with rail connections and a loading platform.

Machine and repair shops are usually medium or small buildings with a continuous monitor on a gable roof. Another clue may be the equipment and machinery standing outside the building.

Change houses are usually small gable roof buildings with 4 or 5 ventilators in their roofs. Parking lots generally nearby.

Thaw sheds are located on a railroad spur near the ore bins. Long low structures resembling snow sheds. Not needed in warm climates.

By-products plants may include arsenic, cadmium, and sulfuric acid plants.

DISTINGUISHING FEATURES OF REFINERIES

The presence of a refinery at a smelter is indicated by the addition of a large gable roof building of moderate height. Where pyrometallurgical refining is used the refinery will have a continuous monitor on the roof and several short stacks. A flue carries the furnace gases and fumes to a baghouse: commonly the same baghouse that treats the blast furnace gases. All actual lead refining operations are accomplished in this single building but associated with the refinery may be other smaller structures whose function is to recover such by-products as gold, silver, tellurium, bismuth and antimony.

Electrolytic lead refineries are also characterized by a single large structure with associated smaller build-

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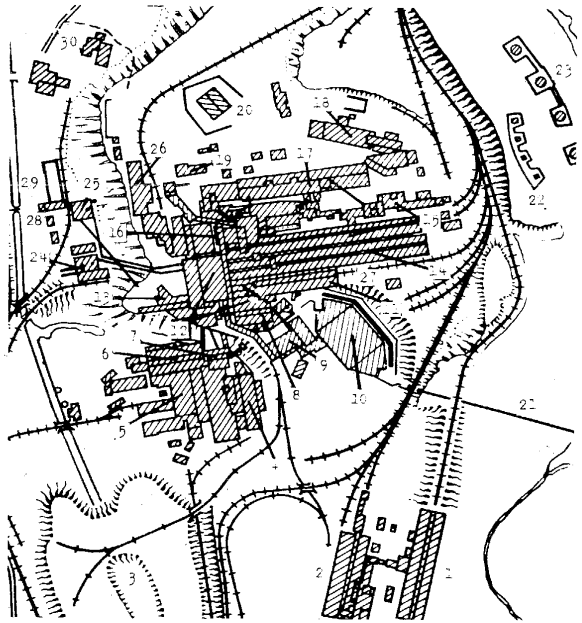
DISTINGUISHING FEATURES OF SMELTERS AND REFINERIES

ings but can be distinguished by the solution tanks, substation, and casting house located near the large electrolytic cell building. Since smoke is not generated in electrolytic refining, large flues, baghouses and stacks will not be in evidence.

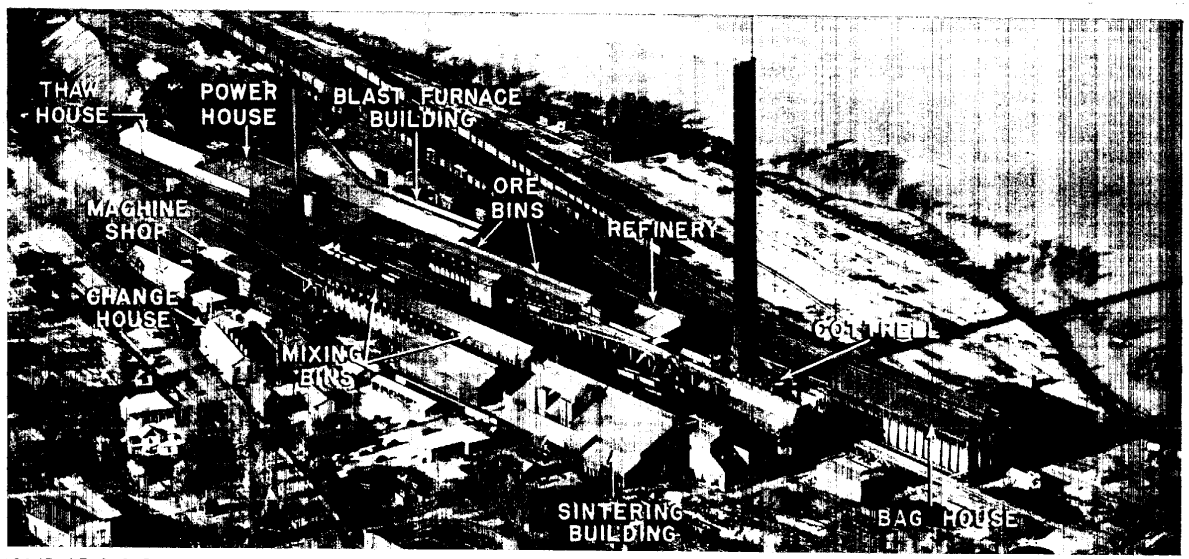
Where refineries exist as individual plants and not as adjuncts to smelters, they require the normal facilities that are common to all industrial plants; power houses, offices, shops, change houses, laboratories, etc.



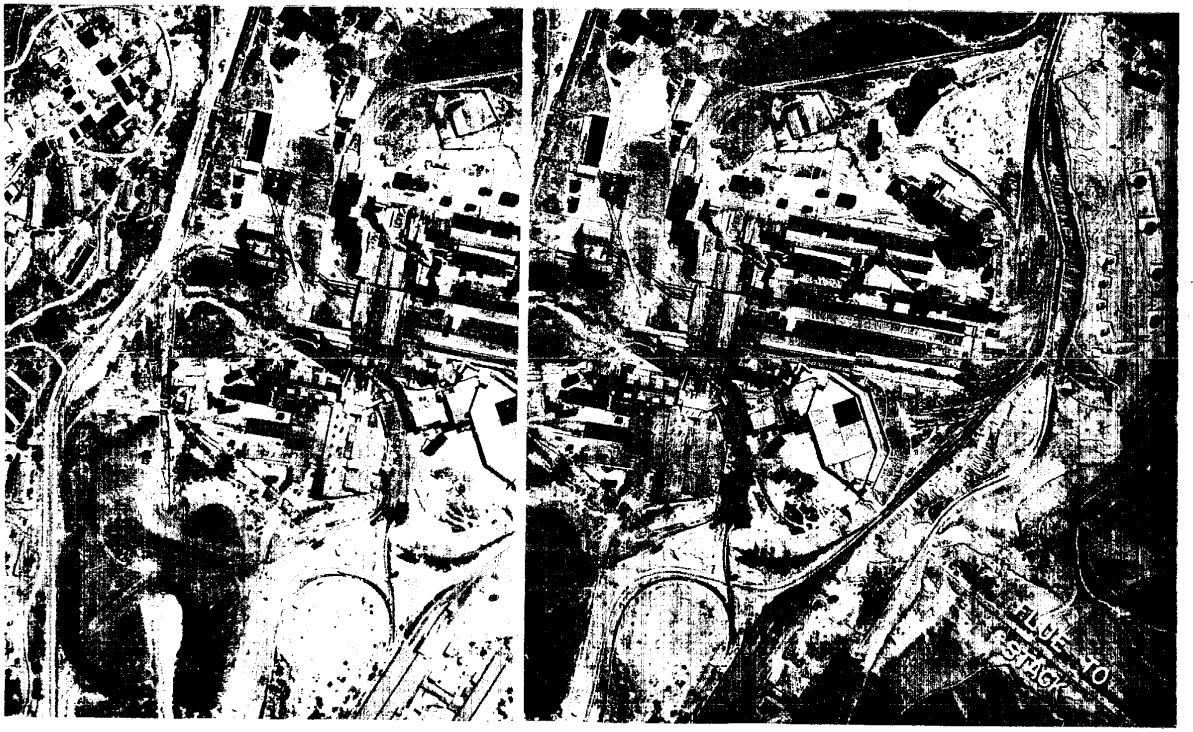
MAP OF NAMTU SMELTER & REFINERY

KEY OF NAMTU SMELTER & REFINERY

1. D.C.P. Unloading & Coarse Storage Bins.
2. D.C. Plant Fine Crushed Storage Bins.
3. Slag Dump. 4. Refinery
5. Refined Lead Loading Platform.
6. Superintendent's Office
7. Silver Room. 8. De-copperising Kettles.
9. Yuille Plant. 10. Dust Chamber.
11. Blast Furnace Improving Furnaces.
12. Blast Furnaces. 13. Blast Furnace Offices.
14. Bedding Bins. 15. Sintering Plant
16. Speiss Grinding & Mixing Plant.
17. Copper Ore Treatment Plant.
18. Smelter Sub-Station.
19. Smelter Mechanical Workshop & Store.
20. Speiss Breaking & Storage Floor.
21. Smelter Flue. 22. Small Oil Storage Tanks.
23. Large Oil Storage Tanks.
24. Steam Plant. 25. Boiler House.
26. Assay Office. 27. Open Coke Storage Floor.
28. Central Time Office.
29. Smelter Water Reservoir. 30. Branch Assay Office.



ABOVE: LEAD SMELTER AND REFINERY - HERCULANEUM, MO. BELOW: STEREO PAIR: LEAD SMELTER & REFINERY - NAMTU, BURMA.



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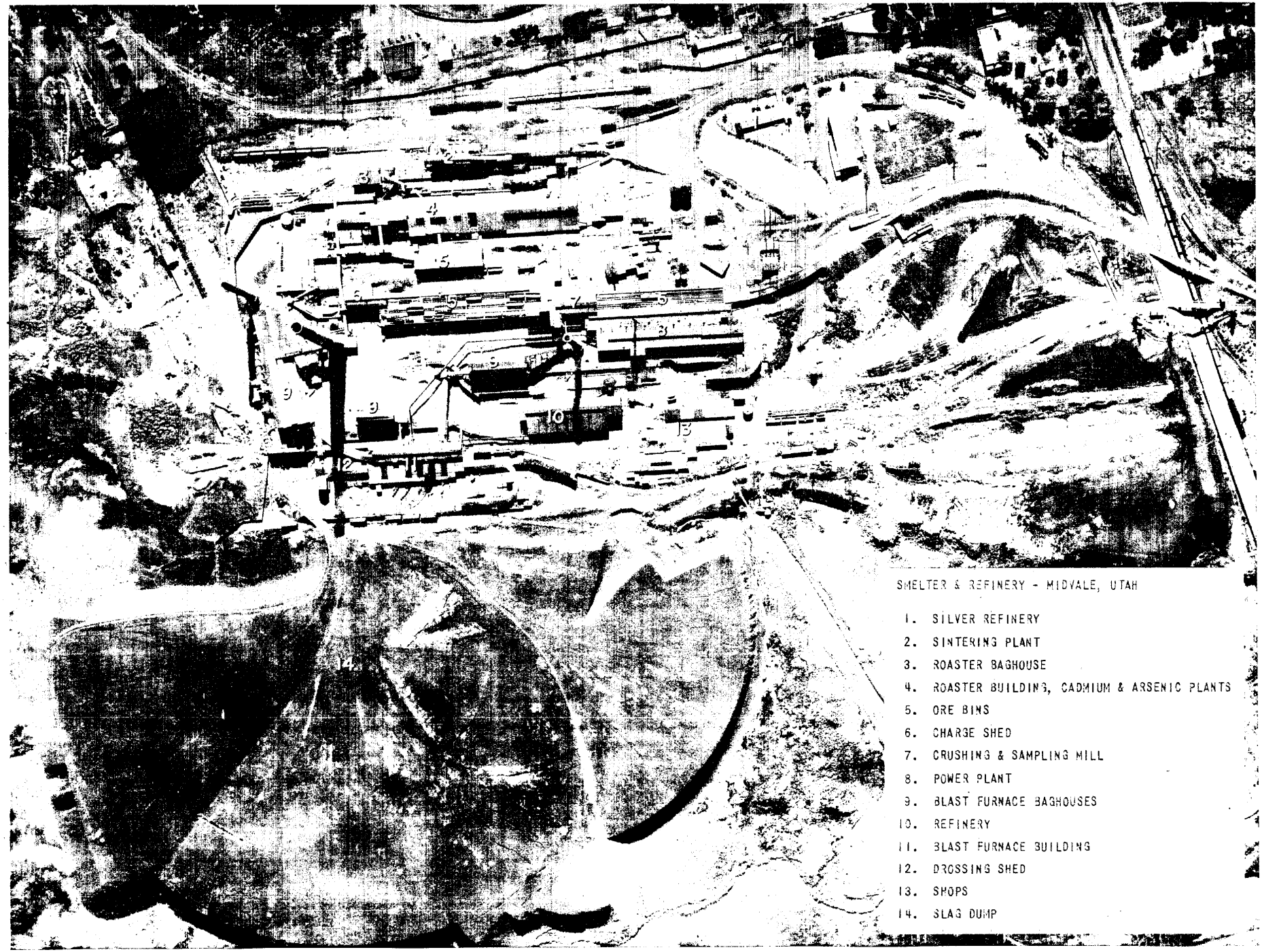

SMELTER & REFINERY - MIDVALE, UTAH

1. SILVER REFINERY
2. SINTERING PLANT
3. ROASTER BAGHOUSE
4. ROASTER BUILDING, CADMIUM & ARSENIC PLANTS
5. ORE BINS
6. CHARGE SHED
7. CRUSHING & SAMPLING MILL
8. POWER PLANT
9. BLAST FURNACE BAGHOUSES
10. REFINERY
11. BLAST FURNACE BUILDING
12. DROSSING SHED
13. SHOPS
14. SLAG DUMP

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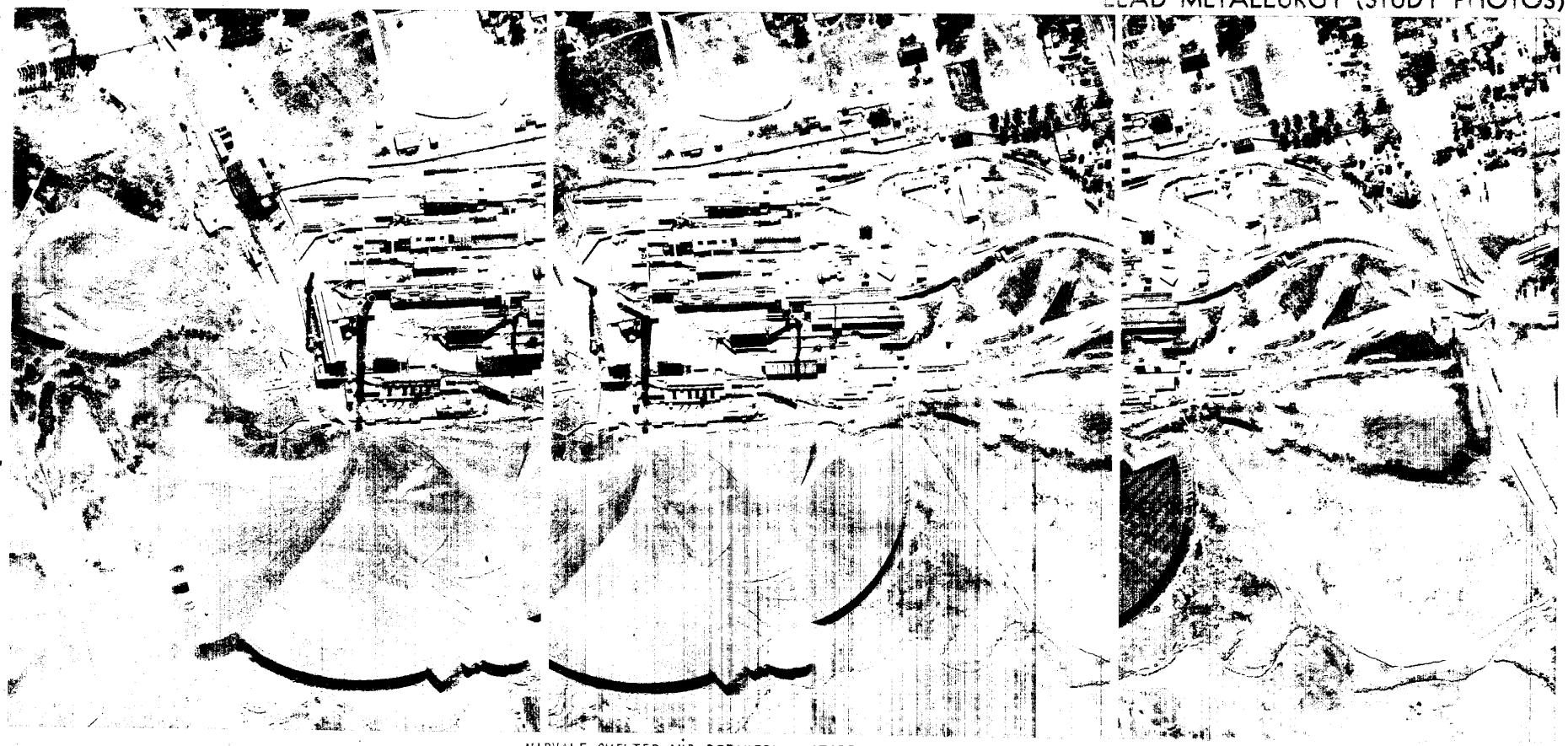
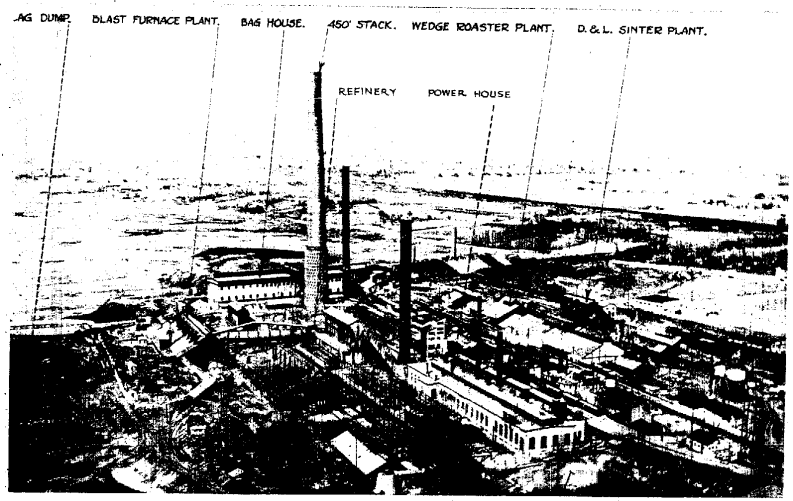
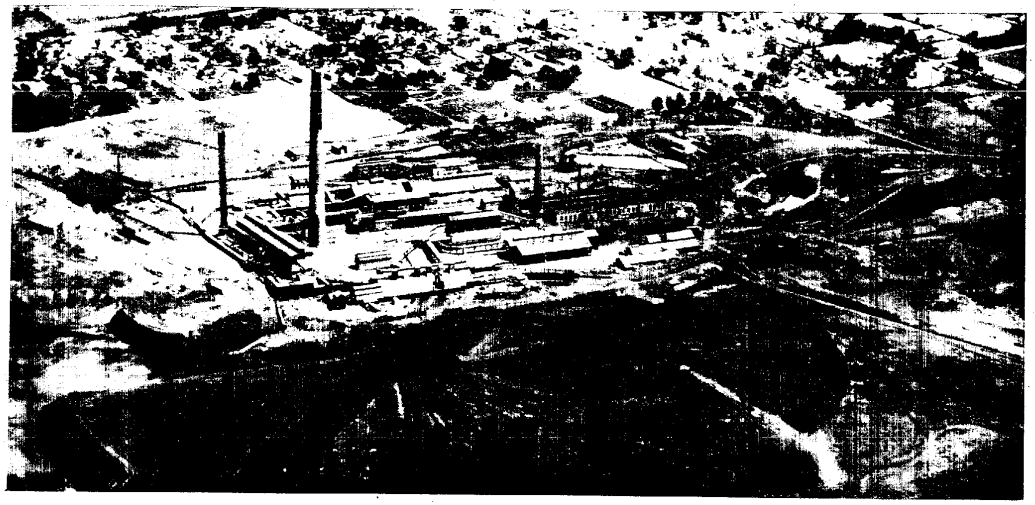


MIDVALE SMELTER AND REFINERY - STEREO AND OBLIQUE VIEWS





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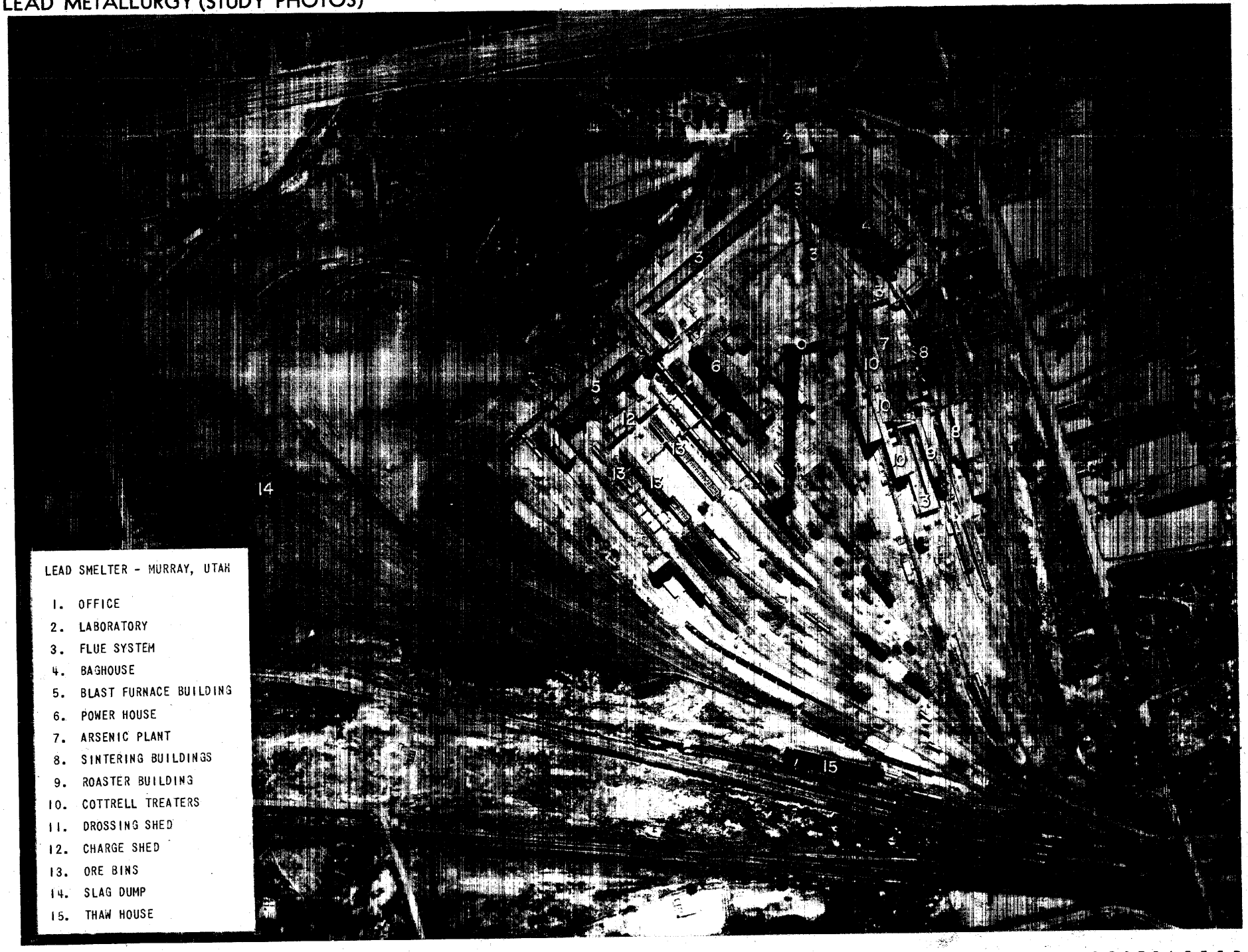
LEAD METALLURGY (STUDY PHOTOS)



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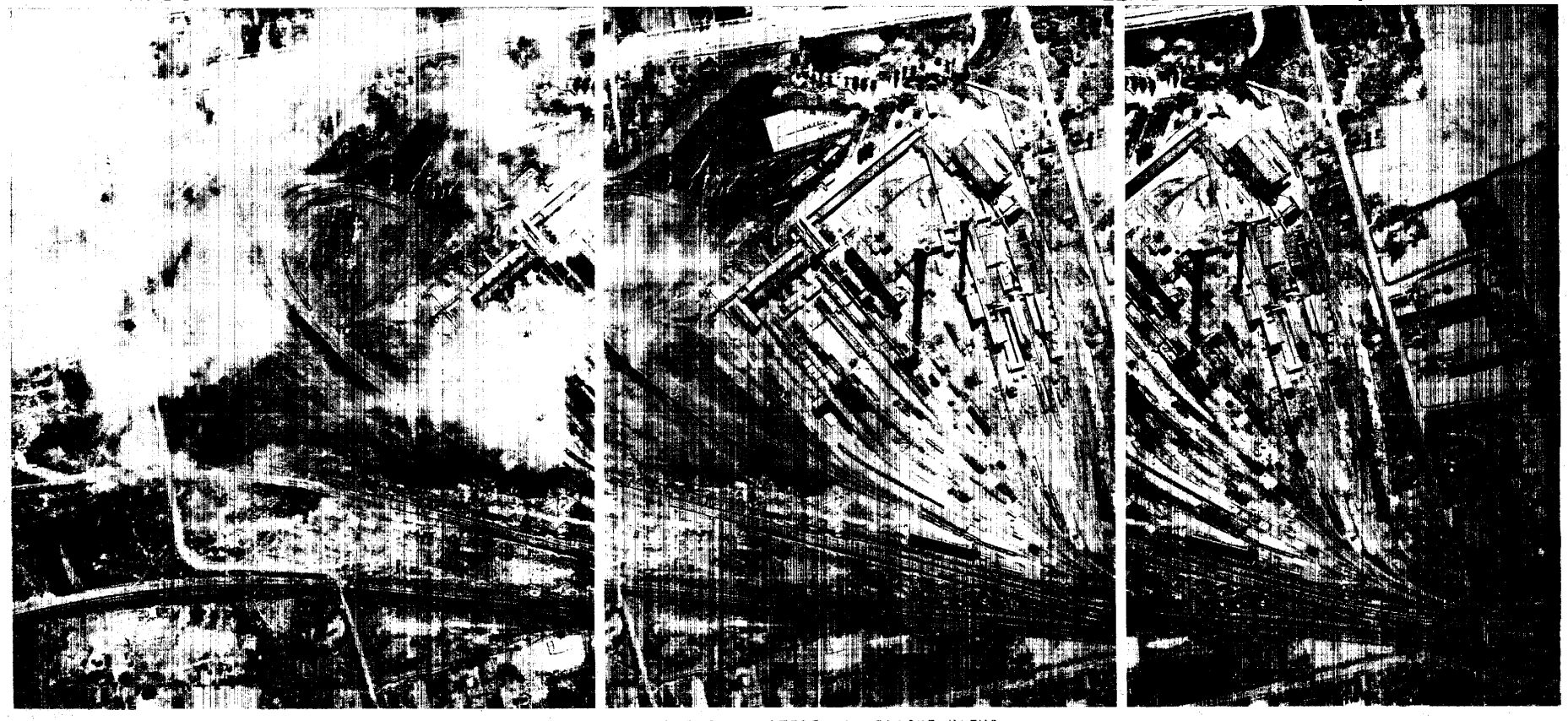
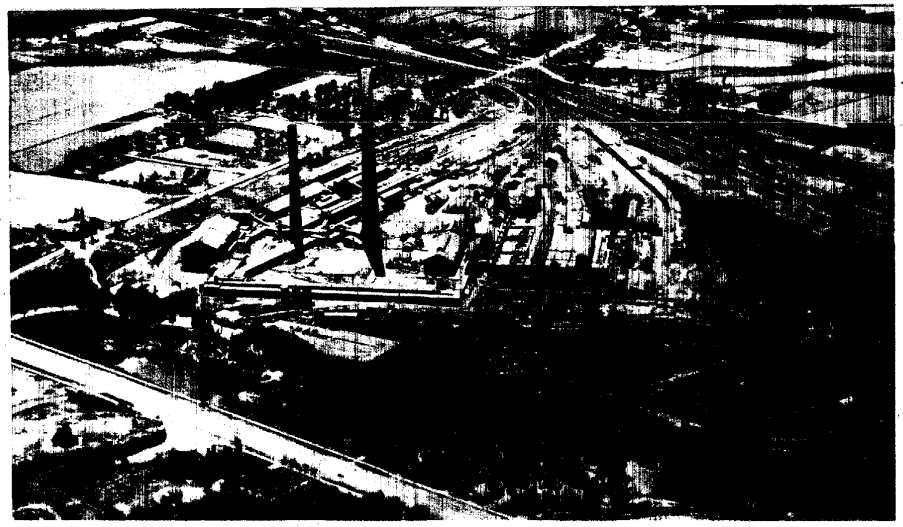
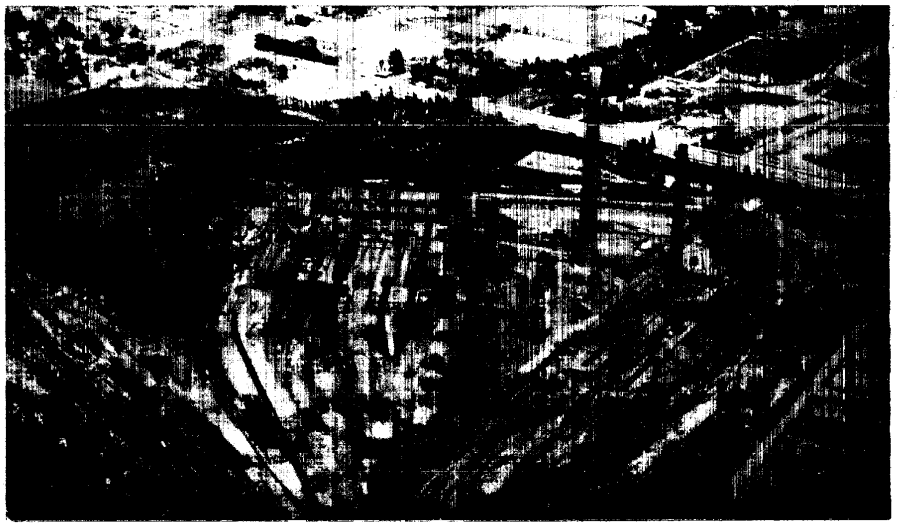


MURRAY SMELTER - STEREO & OBLIQUE VIEWS





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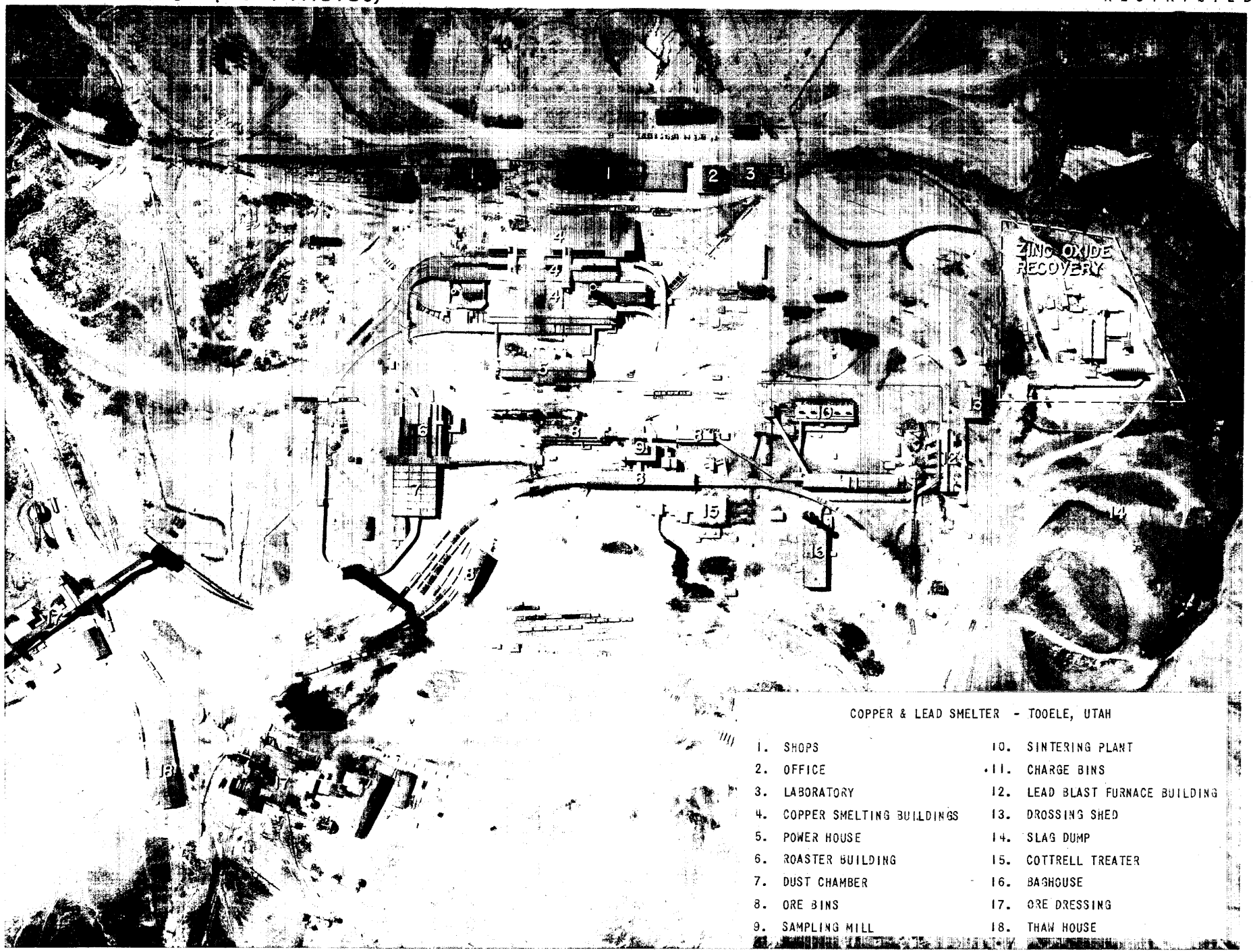

COPPER & LEAD SMELTER - TOOELE, UTAH

1. SHOPS	10. SINTERING PLANT
2. OFFICE	11. CHARGE BINS
3. LABORATORY	12. LEAD BLAST FURNACE BUILDING
4. COPPER SMELTING BUILDINGS	13. DROSSING SHED
5. POWER HOUSE	14. SLAG DUMP
6. ROASTER BUILDING	15. COTTRELL TREATER
7. DUST CHAMBER	16. BAGHOUSE
8. ORE BINS	17. ORE DRESSING
9. SAMPLING MILL	18. THAW HOUSE

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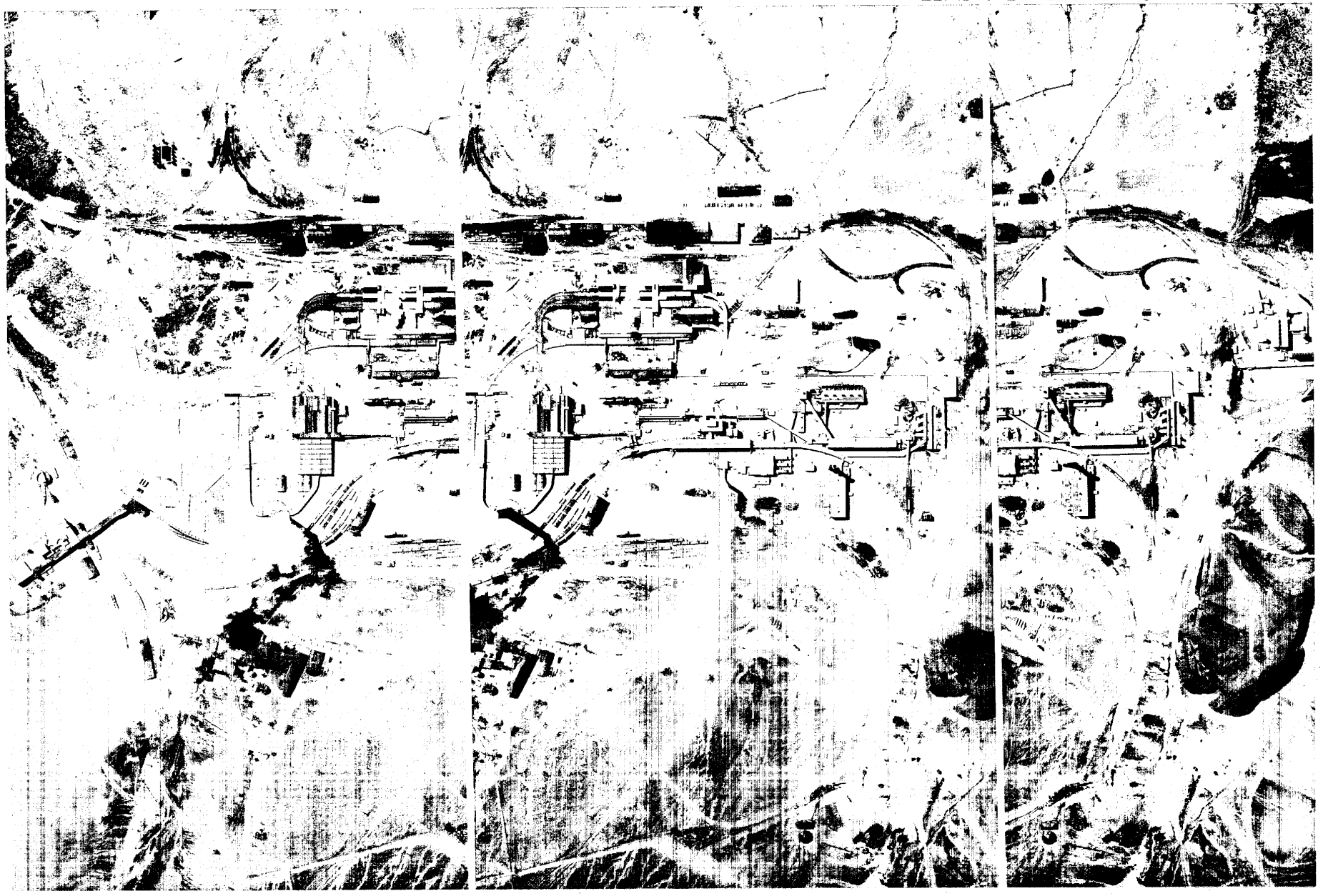

TOOELE COPPER AND LEAD SMELTER - STEREO VIEW

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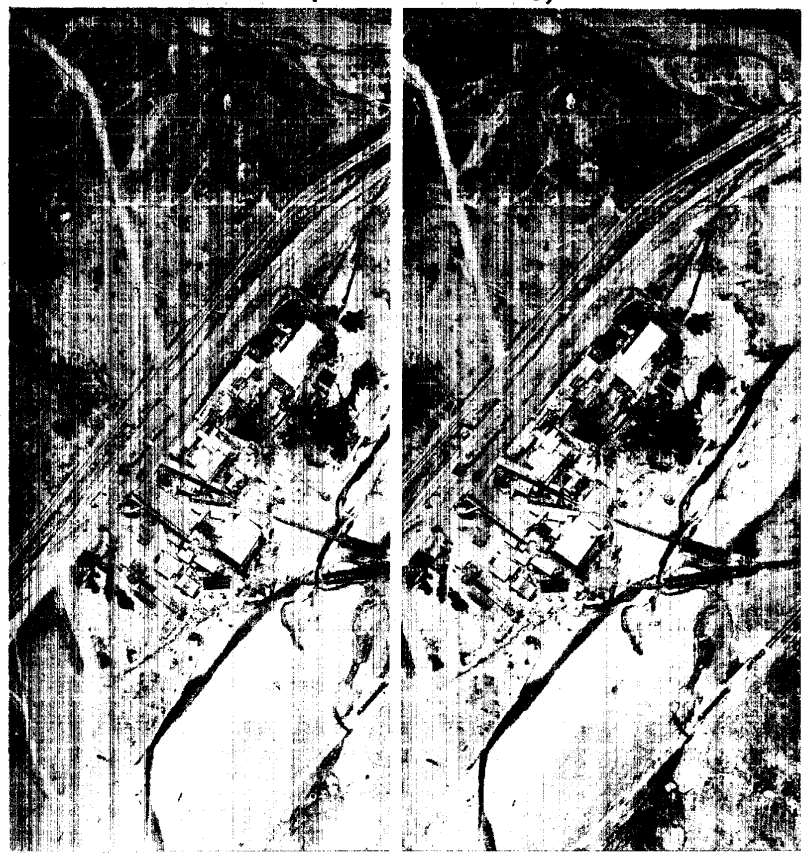
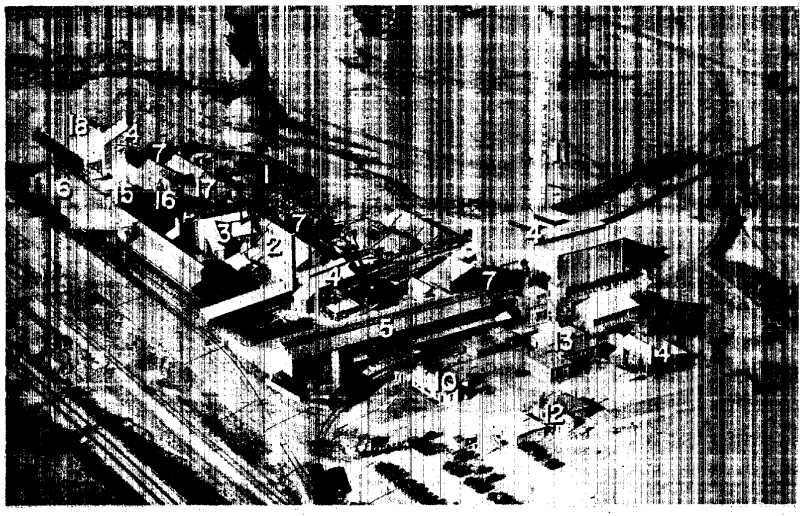
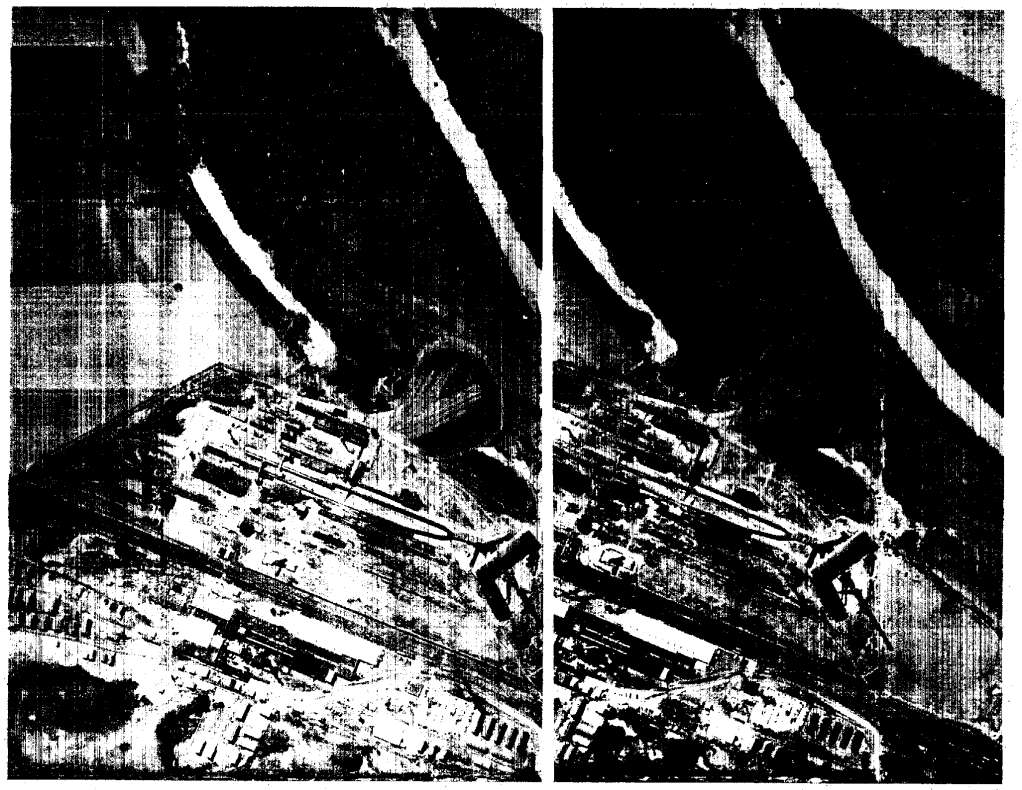


EAGLE PICHER SMELTER, REFINERY & WHITE LEAD PLANT - STEREO & OBLIQUE VIEWS

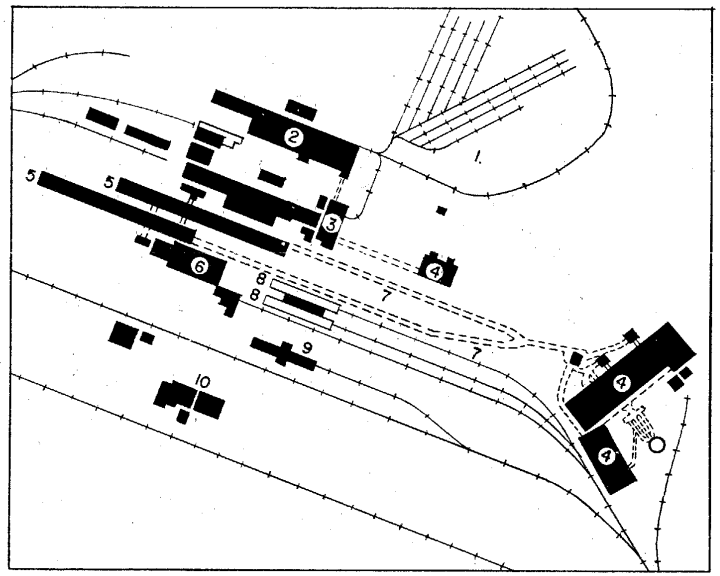




ALTON ORE HEARTH SMELTER - STEREO VIEW & MAP

K E Y

1. SLAG DUMP
2. DROSSING & CASTING BLDG.
3. BLAST FURNACE BLDG.
4. BAGHOUSES
5. HEARTH FURNACE BLDGS.
6. ORE SHED
7. FLUES
8. ORE BINS
9. THAW HOUSE
10. MAIN OFFICE
11. STACK
12. LABORATORY
13. DINING ROOM
14. SHOP
15. SINTERING BLDG.
16. WHITE LEAD PLANT
17. ZINC OXIDE PLANT
18. WHITE LEAD & ZINC OXIDE WAREHOUSE



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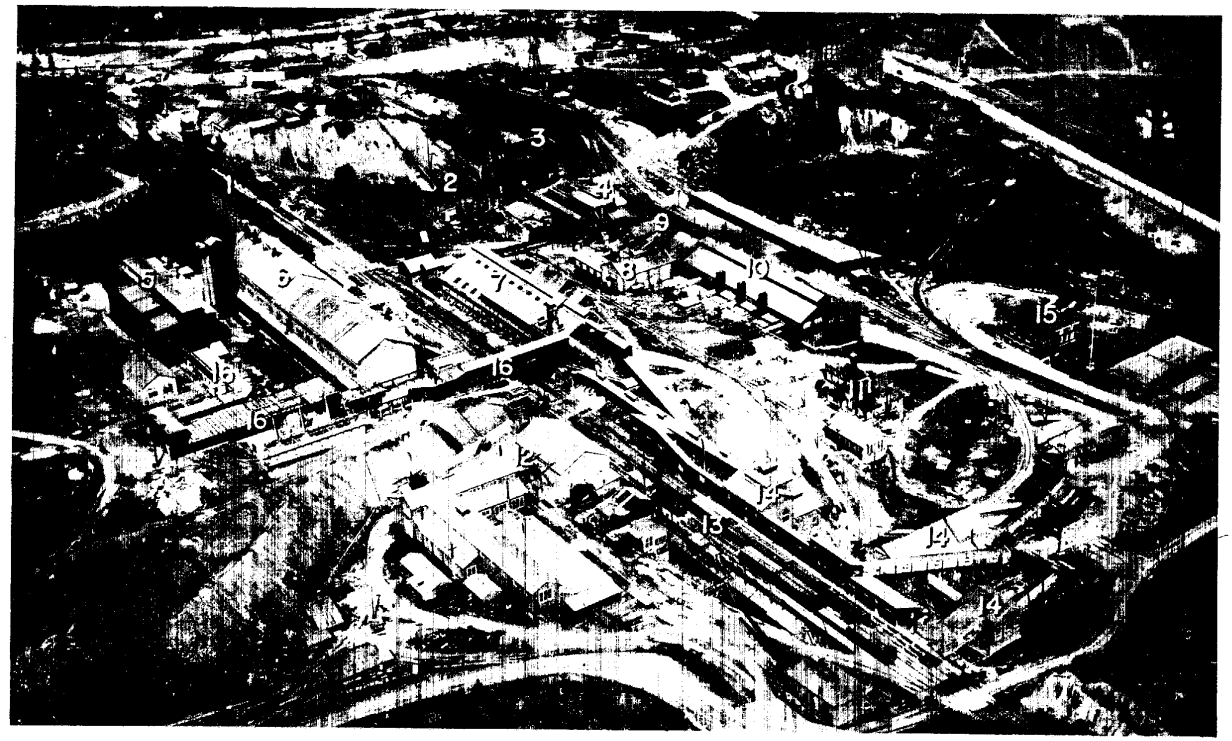
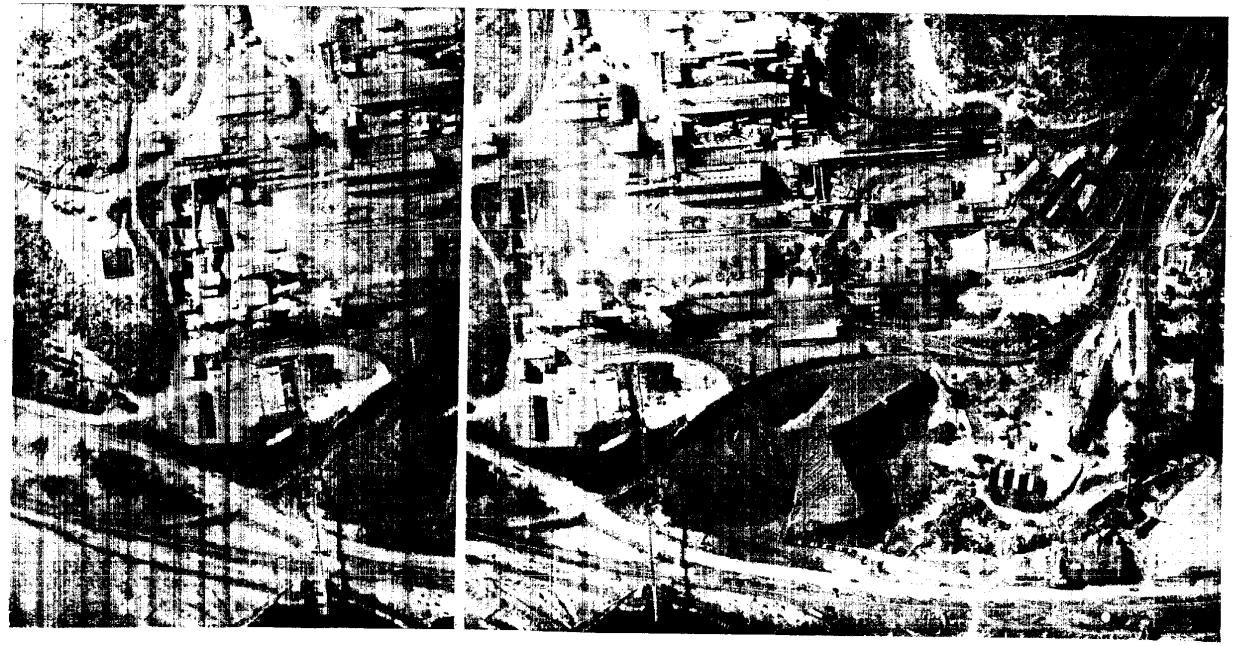


BUNKER HILL SMELTER - STEREO AND OBLIQUE VIEWS KEY - UPPER RIGHT



LEAD METALLURGY (STUDY PHOTOS)

1. CHARGE BINS
2. COPPER SULFATE PLANT
3. COAL BINS
4. GOLD & SILVER RECOVERY
5. COTTRELL TREATER
6. BAGHOUSE
7. SINTERING PLANT
8. SUBSTATION & BLOWER HOUSE
9. REFINERY
10. BLAST FURNACE BLDG.
11. ASSAY OFFICE
12. SHOP
13. ORE BINS
14. CRUSHER & SAMPLING BLDGS.
15. OFFICE
16. FLUE SYSTEM

VULNERABILITY

Since the methods and equipment involved in producing lead are similar to those involved in producing copper, the factors considered in determining the relative vulnerability of copper mines, mills, smelters, and refineries can be equally as well applied to the corresponding lead facilities. Here again from a theoretical standpoint smelters and refineries are considered better targets than mines or mills but in the particular case of Japan where there is an excess of lead smelting and refining capacity and an ore shortage this may not hold.

With the present information it is not possible to ascertain whether attacks directed against mines and mills would have a more serious effect on metal output than attacks against smelters and refineries which may already be partially idle due to an insufficient ore supply.

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LEAD METALLURGY

VULNERABILITY OF SMELTERS AND REFINERIES

VULNERABILITY OF INDIVIDUAL SMELTER AND REFINERY UNITS

Of fundamental importance in determining the vulnerability of individual units is the degree of dependence of the plant on the specific operation under examination. Another factor to be taken into consideration is the time required to repair the damaged or destroyed unit which in turn hinges upon the construction of the equipment and its availability. A third factor is the combustibility of the building, its equipment, and stored materials, although, as has been pointed out in the copper section, metallurgical plants are ordinarily regarded as poor incendiary targets since most of the vital smelting and refining operations entail the handling of incandescent matter and consequently the buildings are constructed of non-combustible materials.

The target value of the component parts of a smelter and a refinery is indicated by their position in the table below. The most vital units are listed first.

SMELTER	REFINERY
Power Supply	Power Supply
Furnace Building	Refining Building
Sintering Building	Cottrells and Baghouses
Charge Mixing Building	By-Product Plants
Drossing and Casting Bldg.	
Cottrells and Baghouses	
By-Products Plants	

The following is a brief description of the importance of each of these units, its equipment and its construction.

Power Supply

It is possible to halt all production by damaging or destroying either the primary power plant or the substation since nearly all operations, particularly grinding, crushing, mixing, and ore conveying systems are mechanized with electric motors. In addition the power plant contains air compressors which supply the air blast to the smelter furnaces. Interruption of the power supply would be particularly effective in halting operations at an electrolytic refinery where the production of refined metal is directly dependent upon a continuous supply of electricity.

Power plant boilers, turbines, and generators are expensive equipment and would probably be difficult to replace readily if destroyed. This also applies to substation equipment which includes transformers and sometimes mercury arc rectifiers and rotary converters.

Direct hits by high explosive bombs would probably be necessary to destroy power plants or substations since they are typically constructed of reinforced concrete or other sturdy non-combustible materials.

Furnace Building

The furnace building is the focal point of all plant activity for here the actual reduction of the ore takes place. While all blast furnaces, of which there are usually 4 or more, would have to be knocked out to effect a complete shutdown, repairing or replacing damaged furnaces would probably be difficult. Where ore hearths are used it would be more difficult to halt production since there are ordinarily 10 or more in operation and they would be easier to repair or replace if damaged.

The furnace building is the largest target at a smelter but is not easily damaged due to its sturdy fire-resistant construction.

Sintering Building

If all sintering machines or roasters were put out of operation production of lead would stop since it is impossible to smelt unroasted sulfide ores in a blast furnace.

Sintering machines could be damaged fairly easily and would be hard to replace although other methods could probably be improvised to sinter the ore. Roasting kilns are of heavy construction, but a blast might tilt them causing the rabble arms to break up the interior brick linings.

Because open flames are present, sintering is normally carried on in corrugated sheet metal buildings with steel girders. Where roasting is employed instead of or in addition to sintering, the roasters may be in a separate structure or they may be enclosed in the same building; if in a separate structure it will be similar in construction to the sintering building.

Charge Mixing Building

This building does not have great target value since it contains easily replaceable standard equipment. The target value is further lessened by the small size of the building and the sturdy construction of its contents. The building itself may be built of any material since hot materials are not handled in the charge mixing operation.

Drossing and Casting Building

Blast furnace bullion is given a preliminary drossing prior to casting, but if the drossing kettles were destroyed the crude bullion could be shipped to refineries with little loss in efficiency. This fact, coupled with the fact that the drossing and casting building and its contents are both sturdily built and non-combustible, gives this unit a low target rating.

Cottrells and Baghouses

Destruction of Cottrells or baghouses would make work at the smelter inefficient and uncomfortable due to large dust losses, but the plant could continue to operate.

Cottrell treaters are small targets but their electrical equipment is delicate and probably difficult to obtain readily. Baghouses are larger but are more difficult to damage seriously and could be repaired easily.

By-Products Plants

The destruction of by-product plants would have at most only a momentary effect on lead production but the by-products themselves may have sufficient value to be worthwhile targets. By-products that may be recovered at the smelter include sulfuric acid, cadmium and arsenic Refineries may recover white lead, silver, gold, tellurium, bismuth and antimony as by-products.

Refining Building

From a vulnerability viewpoint there are only two important units at a refinery; (1) The power house, and (2) The main refining building where all of the actual lead refining operations take place. There are numerous auxiliary buildings such as warehouses, shops, offices, laboratories, and by-product plants, but their destruction would have comparatively minor effect on the amount of lead refined.

At Parkes process refineries the softening furnaces, kettles, skimming apparatus, retorts, cupeling furnaces, and casting wheels are all housed in a large concrete, brick, or corrugated sheet metal building. At electrolytic refineries the building enclosing the cells and bumps may be constructed of any material since the operation does not involve the handling of hot matter.

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SECTION 4

ZINC METALLURGY

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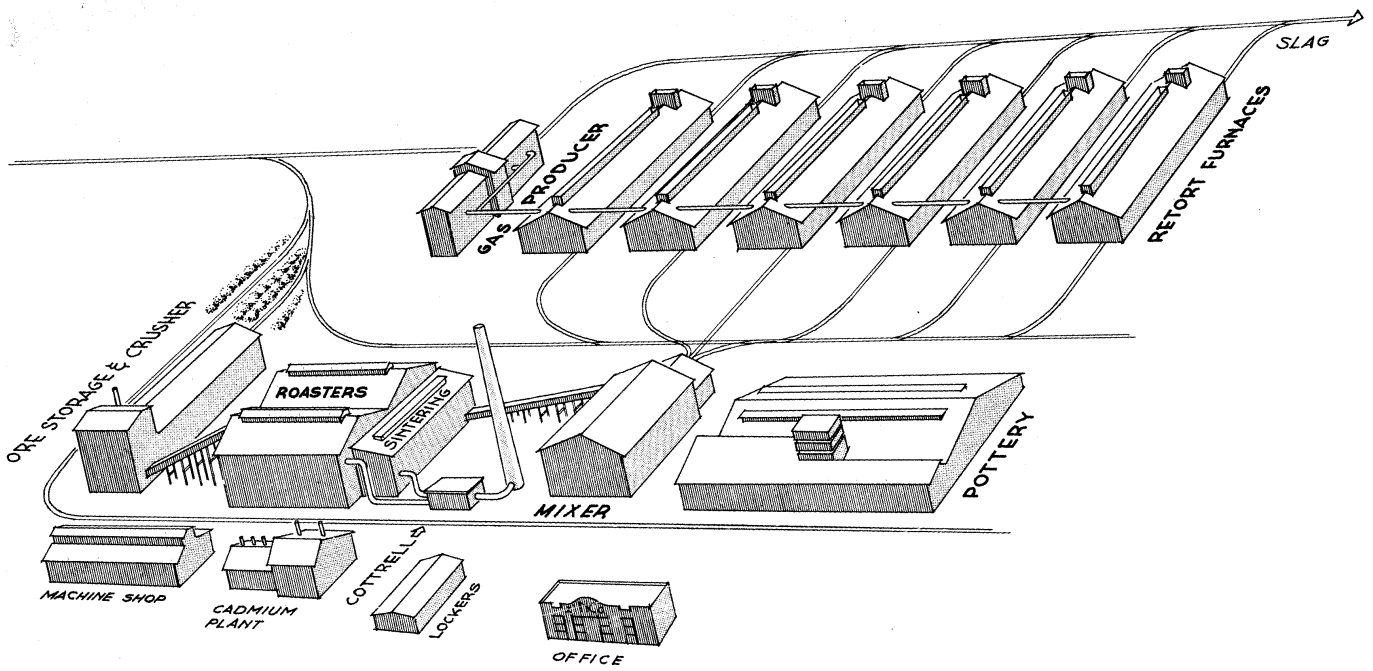
RESTRICTED

TYPICAL HORIZONTAL RETORT ZINC PLANT



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ZINC METALLURGY

HORIZONTAL RETORT SMELTING PROCESS

INTRODUCTION

The physical and chemical properties of zinc preclude the utilization of the same metallurgical techniques and equipment that are employed to extract copper and lead from their ores. When smelted by pyrometallurgical means, the reduction of zinc ore and the vaporization of the resultant molten metal are simultaneous. Consequently the zinc furnace requires, in addition to the smelting chamber, a relatively cool oxygen-free extension where the vapors can condense and the metal accumulate. Two pyrometallurgical methods have been developed, namely the horizontal and vertical retort methods, which together produce the bulk of the world's zinc. The horizontal retort method is the oldest and most inefficient of the smelting methods, and yet under certain economic conditions it is the most satisfactory as evidenced by the fact that approximately 40% of Japan's zinc is produced in this manner. Many advantages have been incorporated in the recently perfected vertical retort method, but at present, smelters of this type account for only 10% of Japan's zinc.

A third extraction method, that of leaching and electrolysis, is well developed both in this country and abroad. The electrolytic process comes into favorable consideration when zinc of great purity is desired and in areas where low cost hydroelectric power is available and coal scarce. Japan, taking full advantage of her hydroelectric power and at the same time attempting to satisfy her needs for high grade zinc, produces 50% of her zinc in electrolytic plants. A fourth type of zinc works, producing not metal but metallic oxide, is also found in Japan. Zinc oxide plants may exist either as separate and independent plants or more commonly as adjuncts to smelters.

Of significance to the photo interpreter is the relation between the smelting and refining of zinc. Unlike copper and lead, zinc does not require extensive refining following smelting. Many zinc smelters possess no refining equipment at all, since there are many industrial uses for crude zinc. When present, refineries occupy but a small portion of the plant. Electrolytic plants are frequently referred to as "refineries" but strictly speaking they are not, since their raw material is ore, not crude metal. The misrepresentation probably arises from the fact that a very high grade zinc is produced by the electrolytic method.

The ensuing pages contain a discussion of the different means of winning zinc from its ore, a description of the equipment, analyses of the vulnerability of component parts of the plants, and a tabulation of features that will aid the photo interpreter in identifying the types of plants and the function of their various buildings.

HORIZONTAL RETORT SMELTING PROCESS

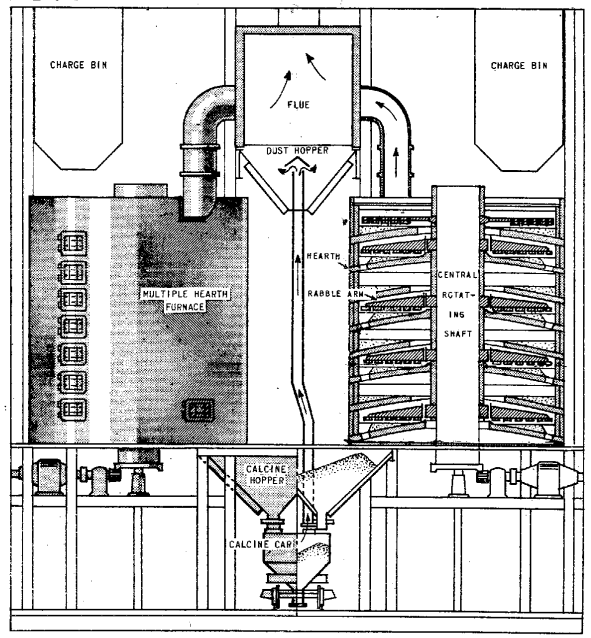
In the horizontal retort method of zinc extraction the concentrates are first roasted to drive off sulfur and convert the zinc sulfide to zinc oxide. Many plants sinter the roasted ore to further reduce the sulfur content, drive off impurities, and to produce a more easily handled furnace charge. The oxidized zinc concentrates are then mixed with fine coal and fed into a retort furnace where the ore is reduced by the coal. The resulting vaporized zinc is condensed to liquid form and is subsequently drawn off and cast into commercial shapes.

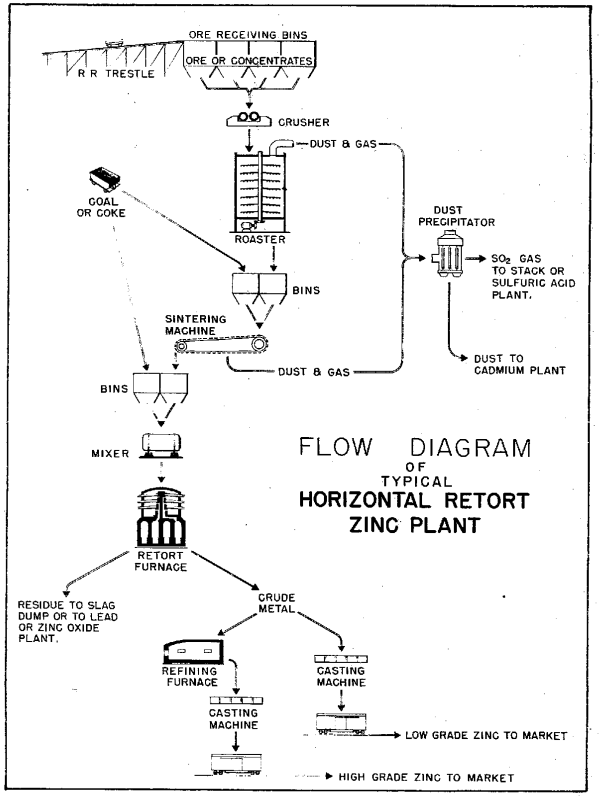
A more detailed description of the steps and equipment involved follows:

ROASTING

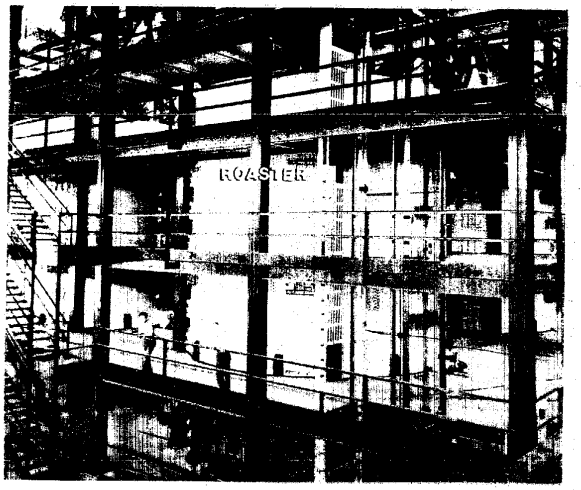
Zinc ores and concentrates arriving at the smelter are primarily sulphides. Since any zinc entering the smelting furnace as a sulphide or sulphate will not be

MULTIPLE HEARTH ROASTERS





INTERIOR OF ROASTER BUILDING



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ZINC METALLURGY

HORIZONTAL RETORT SMELTING PROCESS

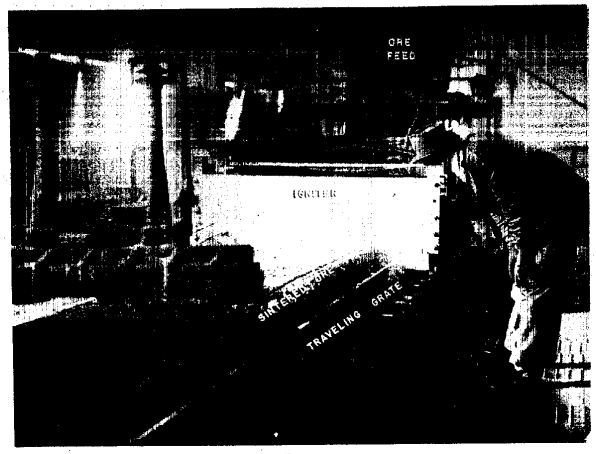
recovered, the initial step in processing the ore is to convert it to the oxide. This is accomplished by roasting the ore in an oxidizing atmosphere where the sulfur is eliminated in the form of sulfur dioxide. There are various patented roasting furnaces in use, but the most popular are the multiple hearth kilns which are standard equipment in smelters where sulfide ores of either copper, lead, or zinc are treated. Multiple hearth furnaces contain a series of brick shelves or hearths encased in a cylindrical steel shell. Air is blown across the burning concentrates as they are raked from one hearth to the next by the rotating rabble arms. The exit gases - rich in sulfur dioxide, are led to dust precipitators where ore particles and vapors carried by the gas stream are settled out. Dust collecting systems are of the same standard type as are used in copper and lead smelters and may be large settling chambers, cyclones, baghouses, Cottrell electrostatic precipitators, or a combination of several of these. In recent years the more efficient Cottrell electrostatic precipitators have, in many plants, replaced the other types of dust collectors. Roaster dust, thus collected, is usually sent to sintering machines or to the cadmium plant for cadmium and lead recovery. The cleaned gas, still retaining its sulfur dioxide content, is either expelled to the atmosphere via a stack or is sent to a sulfuric acid plant.

Roasting practice varies; some plants give the concentrate a partial roast in a multiple hearth kiln followed by sintering to complete the desulfurization, while other plants completely desulfurize the ore in the roasters. In the latter case the calcined material is fed directly to the retort furnaces.

SINTERING

As mentioned above sintering is an optional operation but is widely employed because in addition to oxidizing the residual sulfur it reduces the quantity of impurities and improves the form of the calcined ore for the final object of smelting.

The usual equipment for sintering is the Dwight-Lloyd machine. It consists of a long moving conveyor, 30 to 40 ft. in length, having a base constructed of grate bars mounted on rollers. The conveyor is filled to a depth of about 6 inches with a layer of material from the mixing bins consisting of partially roasted ore fine coal or coke, and water. This mixture passes under an intense flame which ignites the fuel and any remaining sulfides in the calcined ore. The combination of heat and draft burns off many of the impurities as well as converting the loose fine ground charge into a porous



SINTERING MACHINE IN OPERATION

coke-like mass ideal for subsequent smelting.

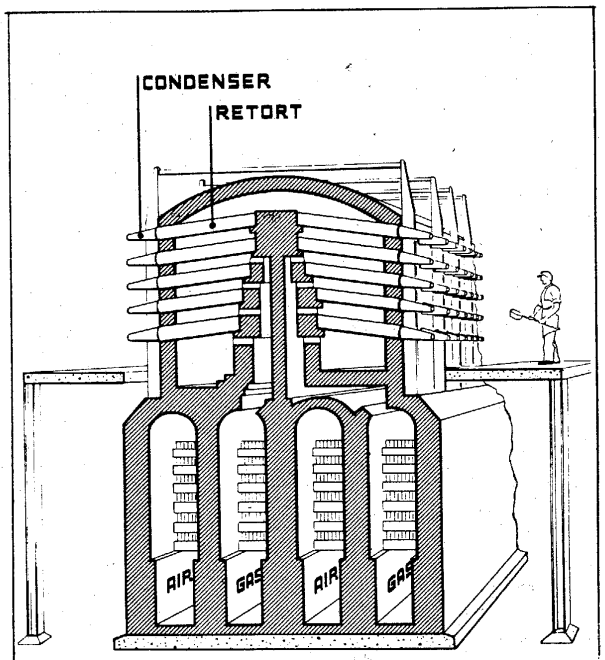
The dust, vapors, and gases liberated by sintering are drawn into wind boxes beneath the conveyor and carried by flues to dust precipitators before being discharged to the atmosphere or a sulfuric acid plant. The dust arrested by the precipitators, containing commercial quantities of cadmium, is sent to the cadmium recovery plant.

REDUCTION OF CALCINED CONCENTRATES.

After roasting and sintering, or simply roasting, the calcined concentrates are transported to a mixing building where they are mixed with coke or coal and stored in bins near the retort furnaces.

Although there are a number of patented retort furnaces with minor variations, the Belgian type furnace is the most common. Overall dimensions depend on the desired capacity, but furnaces 20' high, 12' wide and 60' long are in general use. These furnaces have a firebrick recuperating pre-heating base and a laboratory in which are suspended rows of retorts; large furnaces containing as many as 600 retorts. Gas, either natural or producer, is generally the furnace fuel although pulverized coal is also used in some localities.

The retorts are refractory clay cylinders about 5 ft. in length and 9 inches in diameter with one end closed and the other open. Inserted in the open end of the retorts are clay condensers which cool and condense the vaporous zinc. Due to thermal stresses and handling the life of a clay retort is between 30 to 40 days and that of a condenser about 7 days. Constant production of retorts and condensers is necessary and consequently



SECTION THRU
HORIZONTAL RETORT FURNACE

nearly all zinc smelters have a pottery plant where clay, silica, sand, and certain fire-resisting materials are mixed and mechanically pressed into the desired form.

Reduction by the horizontal retort method is a "batch" or intermittent process. A furnace campaign covering charging, distilling, and discharging usually takes 24 hours and has the following steps.

(1) Charge the hot empty retorts with roasted ore mixed with about 35 per cent coke or coal.
(2) Put the clay condensers in place and lute the joint between condensers with clay or fine moist coal dust.
(3) Continue heating until the charge has been raised to about 1150° C causing the reaction ZnO+C (in excess) = Zn+CO. The zinc is in the form of vapor and passes with the CO gas into the condensers where the zinc deposits as liquid and the CO passes on to be burned at the mouth of the condensers.
(4) Collect the zinc by drawing it from the condensers into a collecting kettle supported on a movable crane. This is usually done 3 times during the

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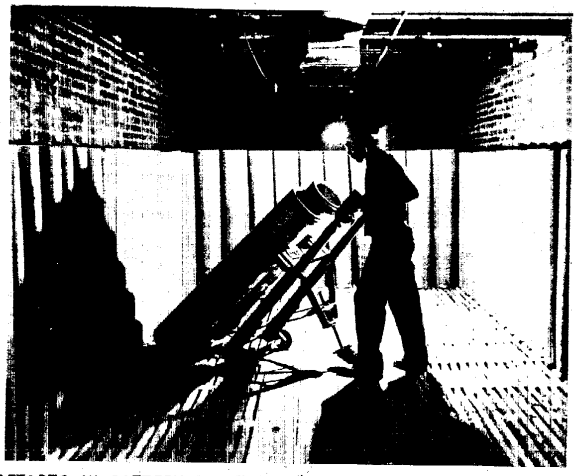
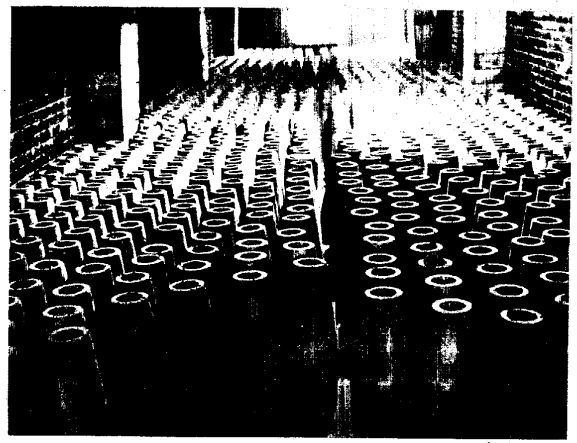


RETORTS IN POTTERY PLANT DRYING ROOM



CONDENSERS IN DRYING ROOM

campaign.

(5) Remove the condensers, clean out the residue from the retorts and start a new campaign.

REFINING

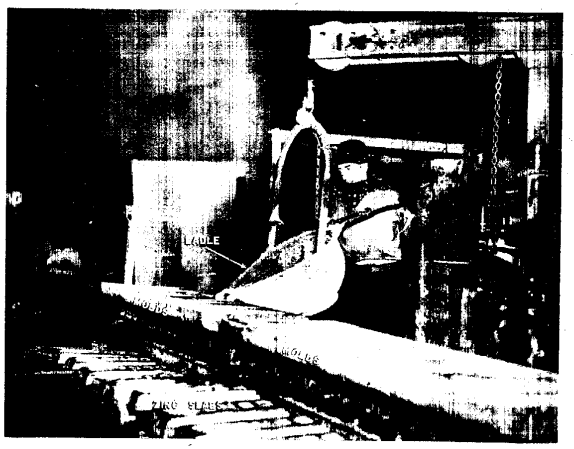
The metal obtained from the retort furnace contains 96 to 98.5 per cent zinc; the impurities are chiefly lead, iron, cadmium, copper, arsenic and antimony. Although this rather impure material is used in certain alloys, low-grade brasses and in galvanizing, it requires refining for many other industrial uses.

Refining is commonly carried on in a reverberatory type of liquating bath where the metal is melted and kept at a temperature just above the melting point for from 24 to 72 hours. During this interval, oxides and impurities rise to the surface as a dross which is skimmed off and returned to the retorts. Lead and a zinc-iron alloy settle to the bottom of the furnace and are removed periodically. The lead, containing some zinc, is usually shipped to lead refineries.

A newer method of refining zinc by redistillation is also in use. The process, employing boilers and rectifying columns, consists of a fractional distillation of the crude metal. Use is made of the difference in the boiling points of the various metals to separate them. Zinc of 99.99 per cent purity can be produced by this method.

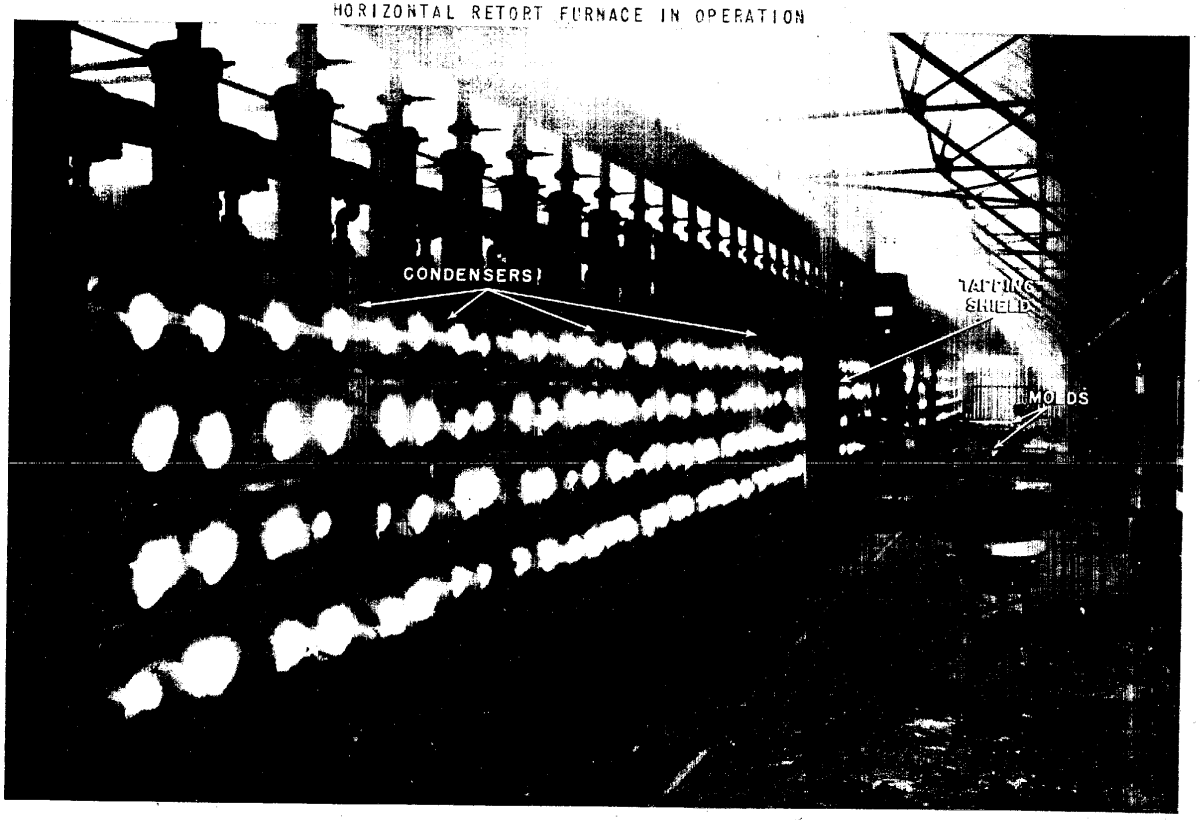
CASTING

The molten zinc drawn from the refining furnace, or the retort furnace if refining is not employed is col-



CASTING CRUDE ZINC

HORIZONTAL RETORT FURNACE IN OPERATION



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HORIZONTAL RETORT SMELTING PROCESS

lected in a melting pot from which it is ladled out and poured in moulds. When cool the slabs, weighing 50 to 60 lbs. each, are removed from the moulds, inspected, and shipped to consumers.

RETORT RESIDUE.

At the termination of the primary reduction cycle the residue left in the retorts is withdrawn and in many cases is merely discarded. However, some plants treat the residue for recovery of zinc while others ship this material to lead smelters where lead and silver are extracted. In American practice there is relatively little recovery of lead or silver from retort residues, but they are sometimes jigged and washed for recovery of undistilled zinc. The Waelz Kiln is also occasionally employed as a scavenger, recovering the remaining zinc as the oxide in baghouses or Cottrell electrostatic precipitators.

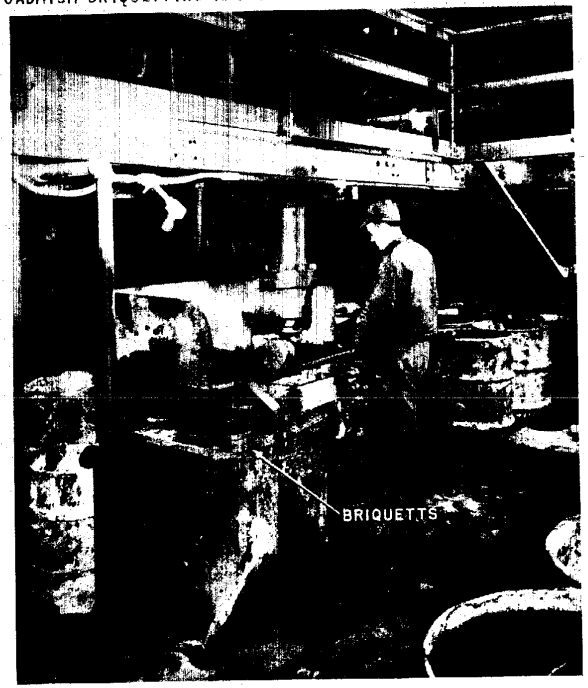
CADMIUM PLANT

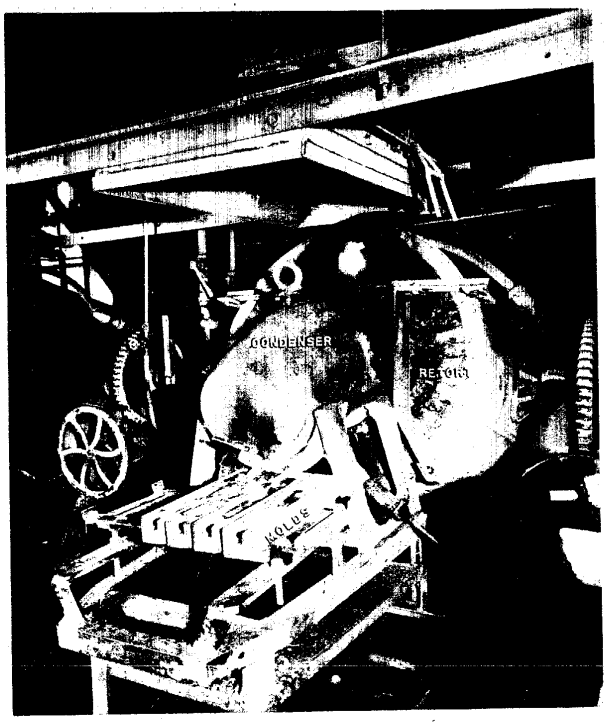
Since cadmium is reduced and volatilized at a much lower temperature than zinc, the dust collected from the combustion gases emitted from roasters and sintering machines normally contains cadmium in commercial quantities. Another source of cadmium is found in the blue powder which collects in the zinc condensers during the first two hours of distillation. This is collected and may contain from 5 to 8 per cent of cadmium.

Most horizontal retort zinc plants use the wet method for the recovery of cadmium from roaster and sinter dust. The dust is leached with sulfuric acid and after thorough agitation the slurry is filtered. The filtrate, containing cadmium and lead in solution, flows to brick-lined lead tanks, cadmium is precipitated with zinc dust, and the resulting cadmium sponge is removed and dried. The sponge is briquetted in a press and distilled in iron or graphite retorts. The metallic cadmium is then melted in a kettle and cast into sticks or balls.

An alternate cadmium recovery method obviates leaching and filtering; the cadmium bearing materials, after having been mixed with ground coke, are charged into retorts and distilled at a relatively low temperature so that only the cadmium is reduced.

CADMIUM BRIQUETTING MACHINE





CADMIUM FURNACE

DISTINGUISHING FEATURES OF HORIZONTAL RETORT PLANTS

Horizontal retort zinc plants exhibit certain characteristics that provide valuable clues to the photo interpreter in recognizing them. While many of the features listed below are common to a number of different types of industrial works, a plant having them all should be carefully examined to determine if the size, shape, and arrangement of the individual buildings is typical of a horizontal retort zinc plant. These features are:

(1) Located along railroad and often along navigable body of water.
(2) Ore cars or ore barges nearby.
(3) Ore piles which are light to dark brown in color.
(4) Black slag piles.
(5) Nearly always a stack at least 200' high. Plants which send their roaster gases to a sulfuric acid plant may or may not have this large stack.
(6) Nearly all buildings have gable roofs.
(7) Many buildings connected by conveyors and/or narrow gage tracks.
(8) Large volume of dense white smoke expelled through roof vents of retort furnace buildings.

The dense white smoke is one of the most important and most easily recognized points of distinction between a horizontal retort zinc plant and other types of metallurgical plants. It must be borne in mind that this zinc oxide laden smoke is expelled through uncapped monitors on the roofs of the furnace buildings and not through the large stack which handles the roaster and sintering machine gases.

DISTINGUISHING FEATURES OF INDIVIDUAL STRUCTURES.

It is not always possible to identify all of the component parts of a plant, especially in older plants where newer and more efficient processes and equipment have been successively installed throughout the years and in plants where local variations, such as terrain, alter the rational layout which would ideally reflect the flowsheet of the process. However, the design of the individual buildings is governed by the technical requirements of the operations and equipment they enclose and consequently buildings having the same function have similar external appearances regardless of their geographical location. In addition to the external appearance of a building there are other clues to its identity such as its position, the stockpiles nearby, and its rail, pipeline, and conveyor connections. Listed below are the features characteristic of the various buildings comprising a horizontal retort zinc smelter.

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ZINC METALLURGY

DISTINGUISHING FEATURES OF HORIZONTAL RETORT PLANTS

Ore conditioning building.

Gable roof building of moderate height with at least one high vertical section to accommodate ore hoists.

Small stack alongside for expulsion of steam liberated by drying kilns.

Ore stockpiles or bins nearby.

Ore car tracks enter or come alongside building.

Conveyors or larry cars transport ore from this building to the roaster building.

Building contents: Ore bins, drying kilns, crushers, and screens.

Roaster building.

Very high building with gable roof.

Commonly continuous monitor on roof.

Roasted ore is moved by conveyors or larry cars to sintering building.

Large flue leading from roasters to main stack or to sulfuric acid plant if present.

Building contents: Roasters, ore hoisting equipment, and often Cottrell treaters.

Sintering building.

Narrow gable roof building of about the same height as the roaster building.

Commonly continuous monitor on roof.

Near and sometimes adjoins roaster building.

Conveyors or larry cars take sintered ore to mixing building.

Flue carries sintering machine gases to main stack or to sulfuric acid plant if present.

Building contents: Sintering machines, ore hoisting equipment, crushers, and mixing machines.

Note: Sintering buildings may not be present; some plants only roast ore.

Mixing house.

Usually relatively small gable roof building.

Nearly square in plan.

At least one elevated section of building to accommodate hoisting equipment.

Ore cars take mixed charge to retort furnace building.

Building contents: Crushers, mixers, ore and coal hoisting equipment, and ore bins.

Horizontal retort furnace building.

Commonly at least 4 of these buildings; all identical.

Relatively long buildings of moderate height and width.

Gable roofs with continuous uncapped monitors.

Dense white smoke expelled through monitors.

Short stack at end of building emits furnace combustion gases.

Slag cars take residue from furnaces to slag dump.

Building contents: Retort furnaces, casting equipment, and sometimes gas producers.

Casting and Refining building

Relatively small gable roof building, low to moderate in height.

Continuous monitor on roof.

One or two short stacks.

Near furnace buildings with railroad track connections to them.

Building contents: Refining furnaces, melting pots, ladles and molds.

Note: This building not always present; many plants ship unrefined metal.

Cadmium plant

Relatively small gable roof building of moderate height.

Small stack to expel cadmium dust.

Usually located near roasters or near roaster dust precipitating unit.

Building contents: Leaching tanks, briquetting machinery, cadmium furnace, and casting equipment.

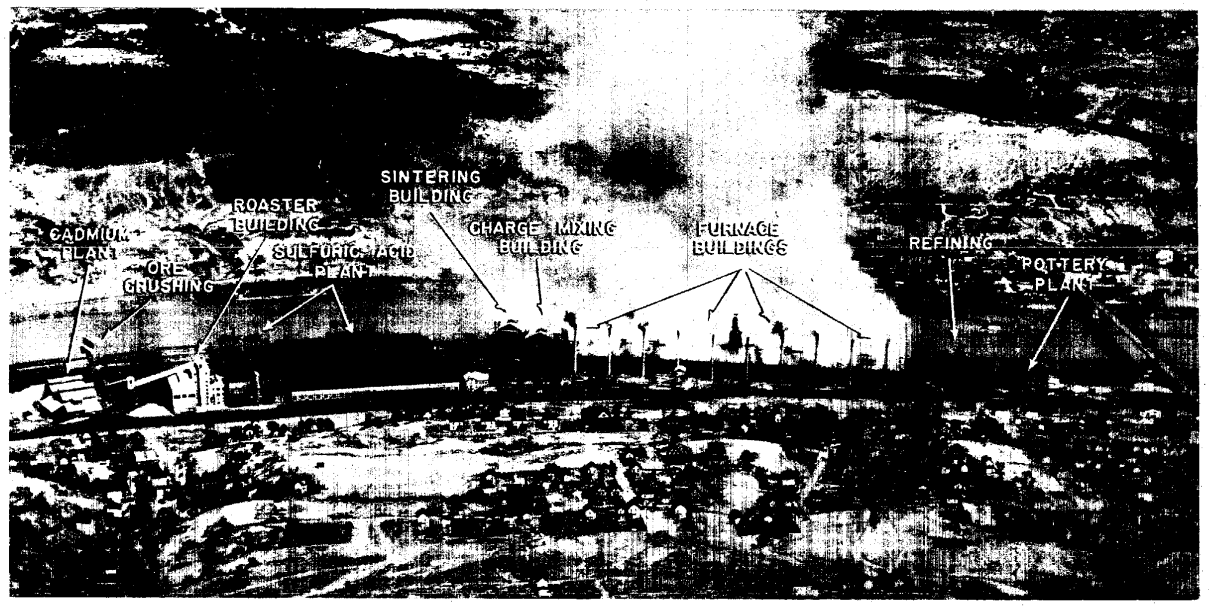
Gas Producer Building

High, narrow, gable roof building.

Usually has continuous monitor on roof.

Large gas mains leave the producer building and enter retort furnace buildings and other points of gas consumption.

DONORA ZINC SMELTER



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DISTINGUISHING FEATURES OF HORIZONTAL RETORT PLANTS

Commonly some steam expelled by gas producers.

Coal pile usually nearby.

Building contents: Coal bins, hoisting equipment, and gas producers.

Note: Gas producer building not always present; gas producers may be located in retort furnace building or natural gas may be available.

Pottery plant.

Large, low, flat roofed building.

One elevated section of building to house clay hoisting equipment.

Numerous ventilators on roof can usually be seen.

Located near and connected by rail to furnace buildings.

Building contents: Clay mixing machinery, mechanical presses, kilns, and drying rooms.

Sub-station

Small, flat roofed reinforced concrete building.

Nearly square in plan.

Transformer yard joins building.

Powers lines enter and leave building.

Building contents: Transformers, switches, control panel, and sometimes converters and rectifiers.

Office

Commonly two-story hip roof or flat roof building.

Located near plant entrance away from disagreeable plant smoke and dust.

Parking lot nearby.

Shrubs or trees often planted at office entrance.

Shop

Gable roof building of moderate height.

Often has continuous monitor on roof.

One or two small stacks.

Tracks usually enter building.

Building contents: Forges, welding equipment, and other repair facilities.

Change House

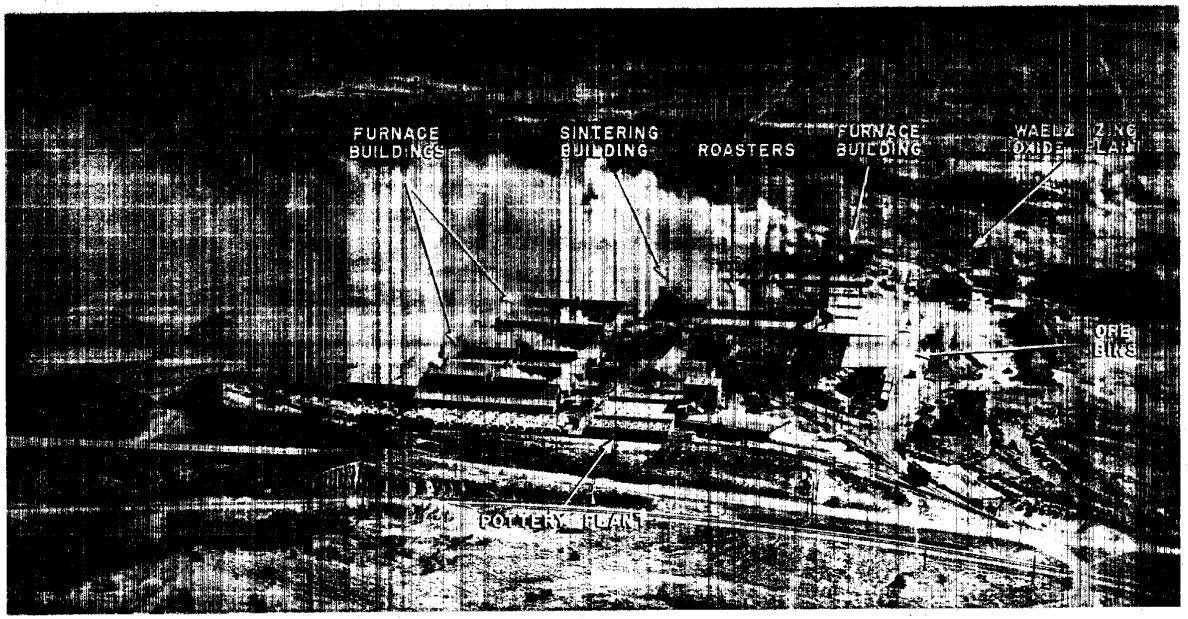
Gable roof building of low to moderate height.

Usually 4 or 5 ventilators on roof.

Commonly near plant parking lot.

Building contents: Clothes lockers, wash basins and showers.

HENRYETTA ZINC SMELTER



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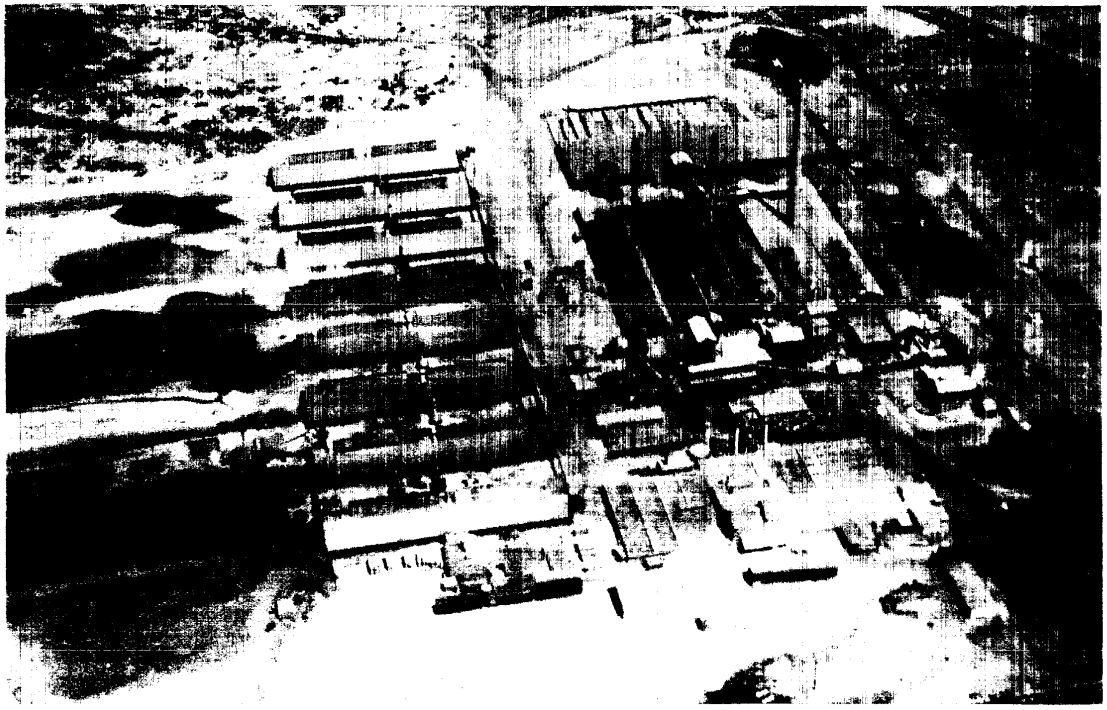
ZINC METALLURGY (STUDY PHOTOS)

DUMAS ZINC SMELTER - STEREO AND OBLIQUE VIEWS

1. SLAG DUMP
2. HORIZONTAL RETORT FURNACE BUILDING
3. POTTERY PLANT
4. LABORATORY
5. CHANGE HOUSE
6. SINTERING BUILDING
7. CADMIUM PLANT
8. ROASTER BUILDING
9. ORE DRYERS
10. ORE STORAGE
11. MAIN OFFICE



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ZINC METALLURGY (STUDY PHOTOS)

BARTLESVILLE ZINC SMELTER - STEREO AND OBLIQUE VIEWS

1. SLAG DUMP
2. HORIZONTAL RETORT FURNACE BUILDING
3. POTTERY PLANT
4. CHANGE HOUSE
5. SHOPS
6. CHARGE MIXING BUILDING
7. SINTERING BUILDING
8. ROASTER BUILDING
9. ORE STORAGE
10. CONTACT SULFURIC ACID PLANT
11. COOLING TOWERS
12. SULFURIC ACID TANKS
13. POWER HOUSE
14. MAIN OFFICE

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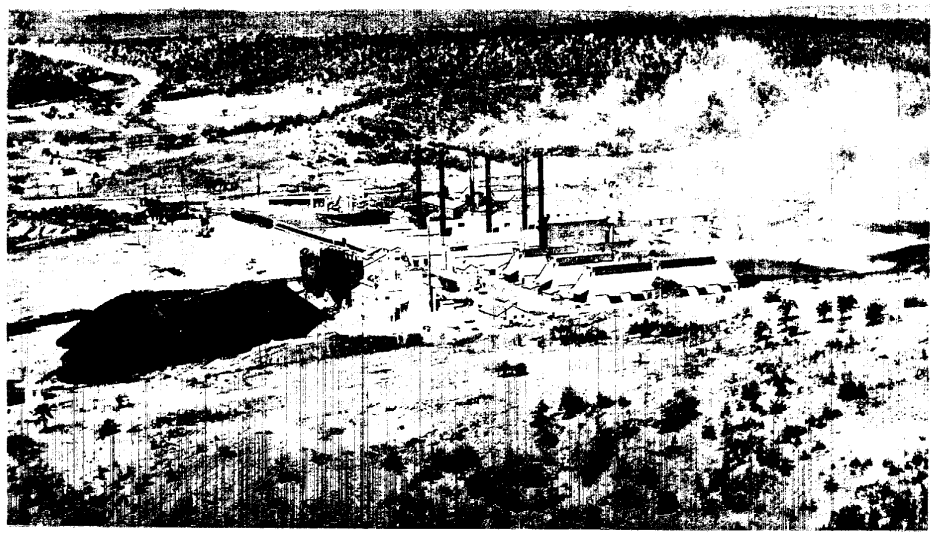
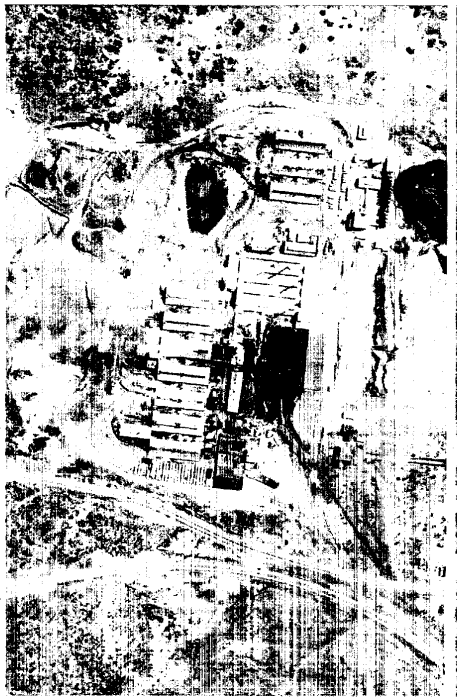
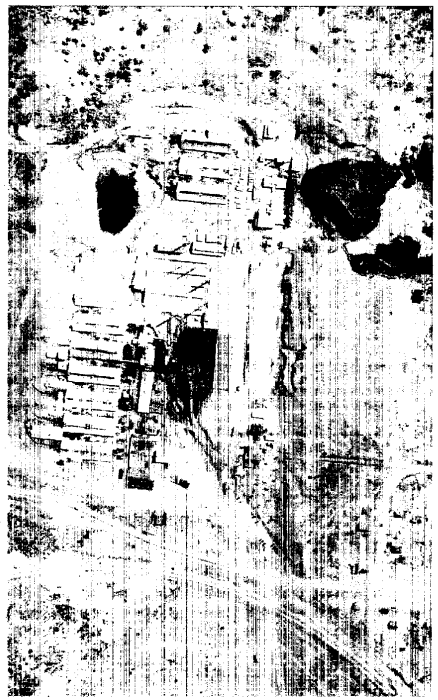
ZINC METALLURGY (STUDY PHOTOS)

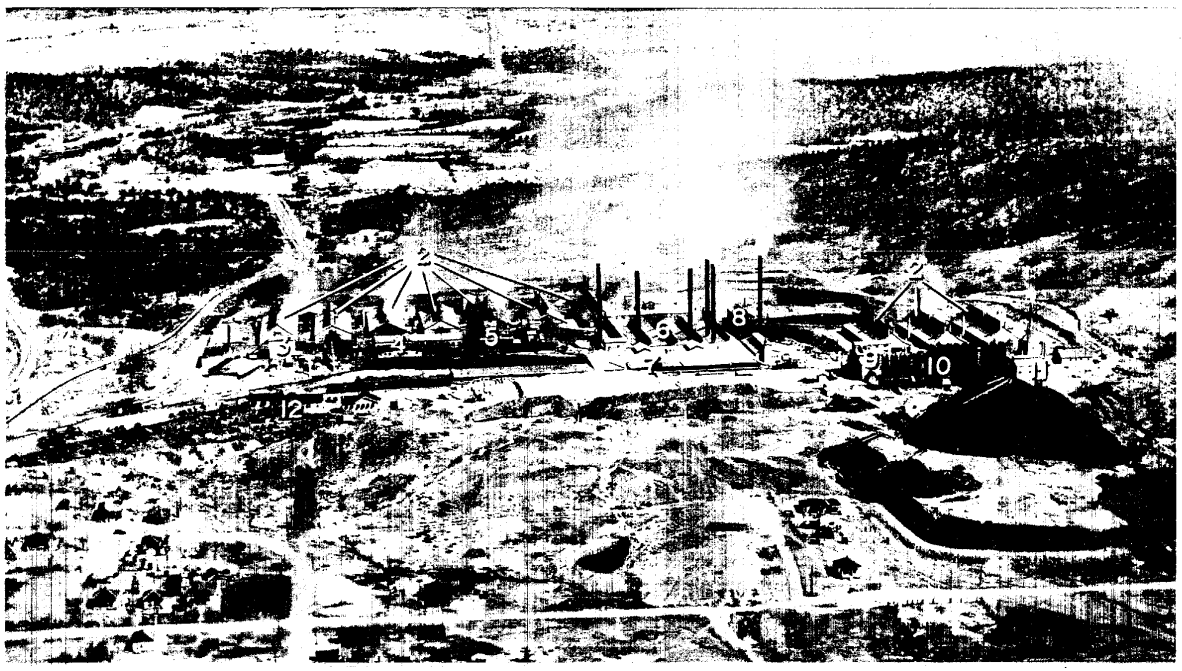






HENRYETTA ZINC SMELTER - STEREO AND OBLIQUE VIEWS

1. ZINC STORAGE
2. HORIZONTAL RETORT FURNACE BUILDINGS
3. POTTERY PLANT
4. STORAGE
5. CHARGE MIXING BUILDING
6. ROASTER BUILDING
7. ORE STORAGE
8. COTTRELL DUST PRECIPITATOR
9. WAELZ ZINC OXIDE PLANT
10. ZINC OXIDE COOLING FLUES
11. ZINC OXIDE COLLECTION HOUSE
12. MAIN OFFICE



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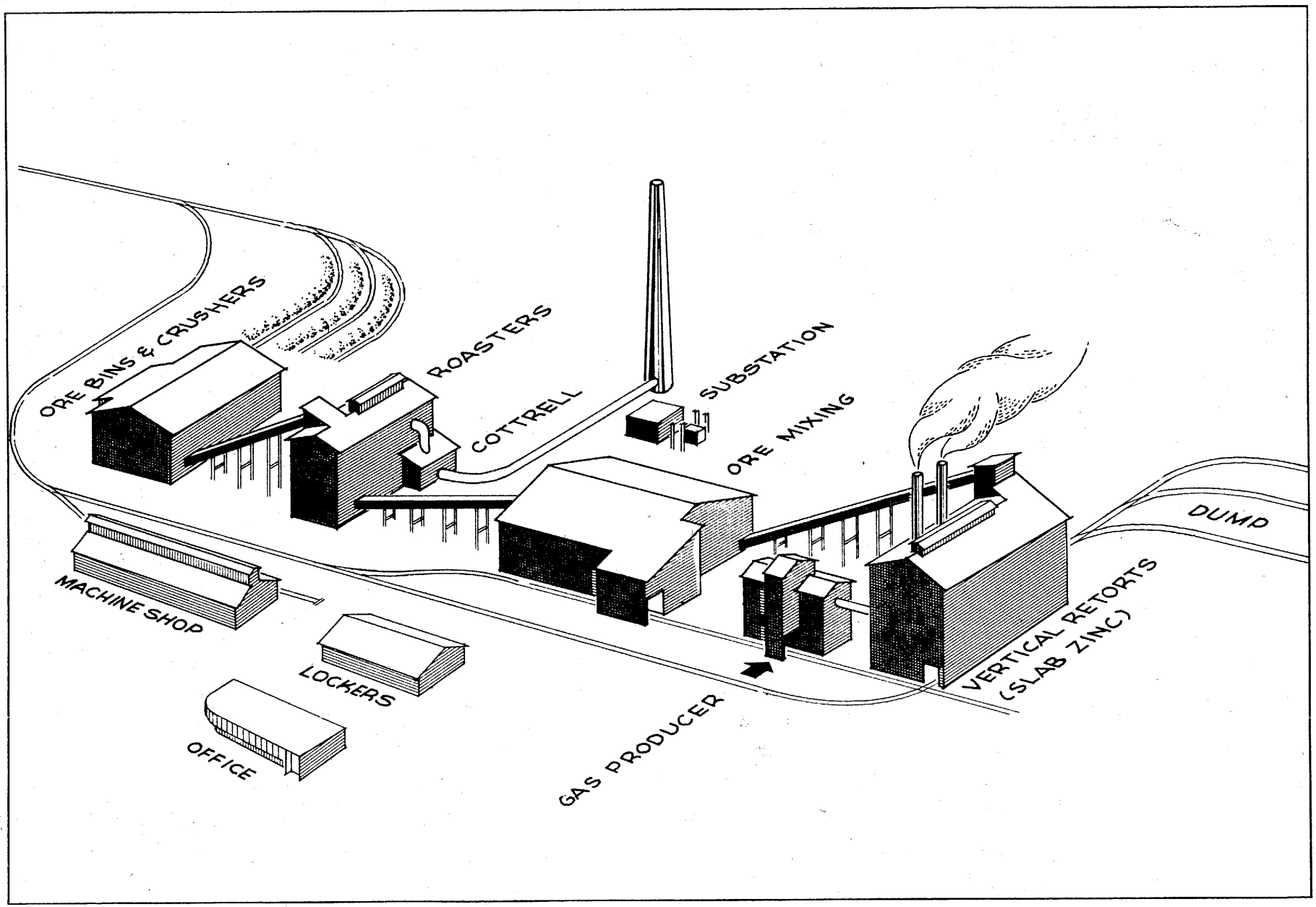
TYPICAL VERTICAL RETORT ZINC PLANT



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VERTICAL RETORT SMELTING PROCESS

The recently developed vertical retort process was advanced to overcome many of the shortcomings of the horizontal retort process. Its advantages over the older horizontal retort process, include: (a) improved recovery of zinc; (b) a product of greater purity than had theretofore been obtainable from ordinary ores by pyrometallurgical methods; (c) lower costs of production; (d) reduction of labor and improved working conditions. These advantages were obtained by utilizing large vertical retorts instead of the small capacity horizontal retorts and by replacing the intermittent or "batch" operations with a mechanized continuous process.

GENERAL DESCRIPTION OF PROCESS

Roasting of the zinc sulfide ores is carried out in a similar manner and with the same equipment that is used in the horizontal retort method. Following roasting the ore is mixed with fine coal and pressed into briquets which are subsequently hardened by coking. The hot coked briquets are charged into the vertical retort where the reduction takes place with the production of zinc vapor. The retort gases, consisting principally of zinc vapor and carbon monoxide, are conducted upwards through the retort, then through the vertical extension of the retort, and finally into a condenser. At appropriate intervals the condensed metal is tapped off and either sent to refineries or cast into slabs.

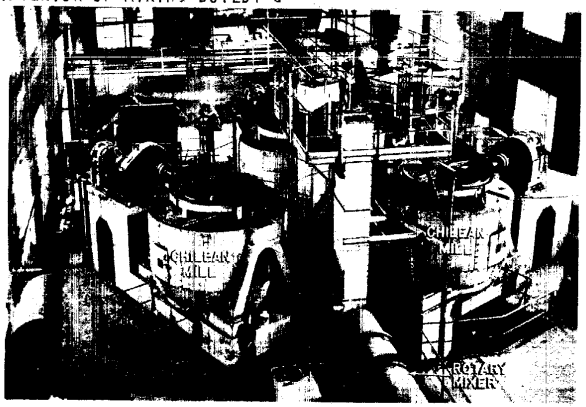
A more detailed description of the process and equipment follows:

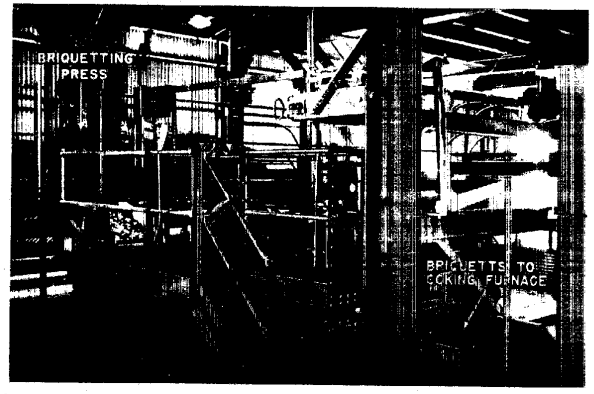
MIXING AND BRIQUETTING.

Efficient operation of the vertical retort requires an agglomerated charge with sufficient voids between the individual agglomerates or briquets to facilitate the passage of gases and vapors up through the retort charge and into the condenser. It is also necessary that these briquets be bonded with a material that will hold them together during the entire smelting period since fines would plug up the interstices of the charge.

The calcined ore to be treated is first mixed with carbonaceous reducing material usually consisting of fine coking coal and anthracite. To this mixture are added an appropriate amount of water and a binder such as sulphite waste liquor, tar, pitch, or molasses. This material is then densified and pressed into briquets which will be fed into the coking furnaces.

INTERIOR OF MIXING BUILDING





BRIQUETTING THE CHARGE

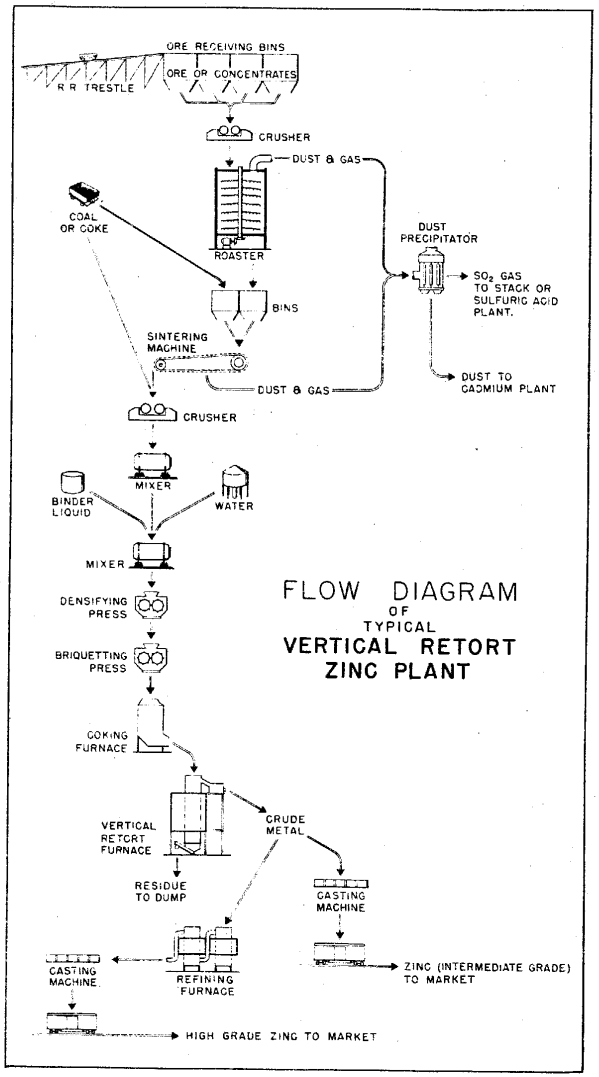
COKING

The primary purpose of coking is to harden the briquets sufficiently to maintain their shape and porosity throughout the reduction campaign. This is achieved by sending the briquets through a chamber which is heated to 800° C. At the discharge end of the coking chamber, the briquets are received by buckets which hoist them to the charging hoppers of the vertical retorts.

REDUCTION

The vertical retort furnace, in which the reduction of the ore takes place, is merely a refractory brick chamber, 25 feet high, 6 feet long and 1 foot wide, encased by a firebox. Heat generated by natural or producer gas in the firebox is transmitted through the walls of the retort to the charge. Above the heated portion of the retort is an extension which is kept filled with fresh briquets about to undergo reduction. Similarly the retort has a lower extension into which the spent briquets drop after reduction.

As the charge slowly descends through the hot retort, metallic zinc is produced by the reactions taking place between the ore and the coal. The heat required for the reduction is of such magnitude that the zinc is vaporized. Gas or air introduced at the base of the retort carries this metallic vapor plus the liberated carbon monoxide up through the retort and into a condenser where the metal is collected.



ZINC METALLURGY

VERTICAL RETORT SMELTING PROCESS

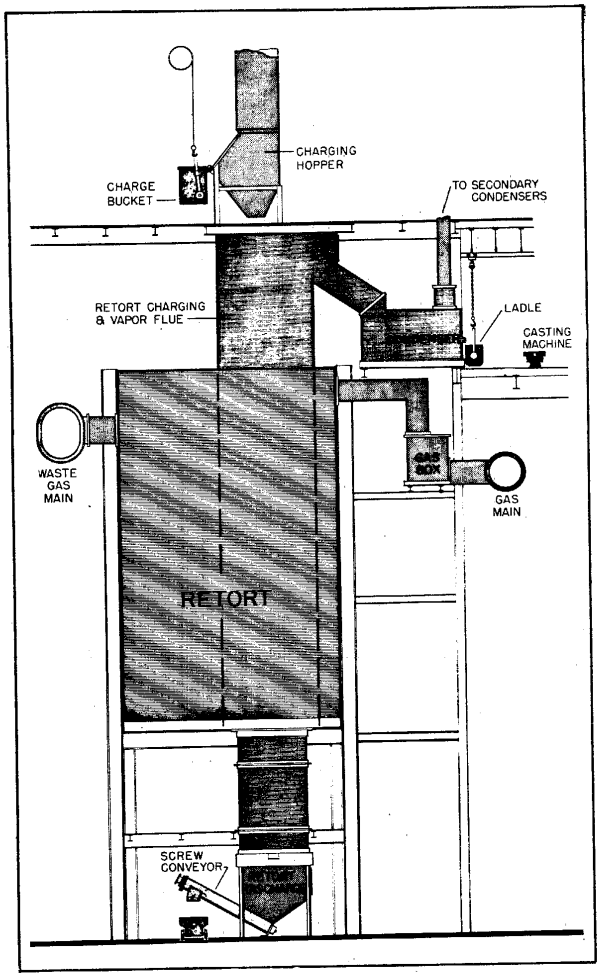
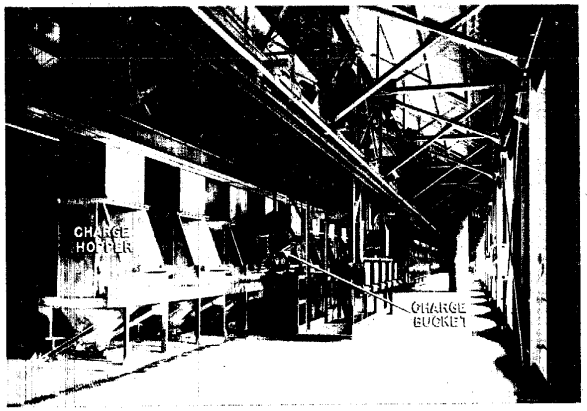
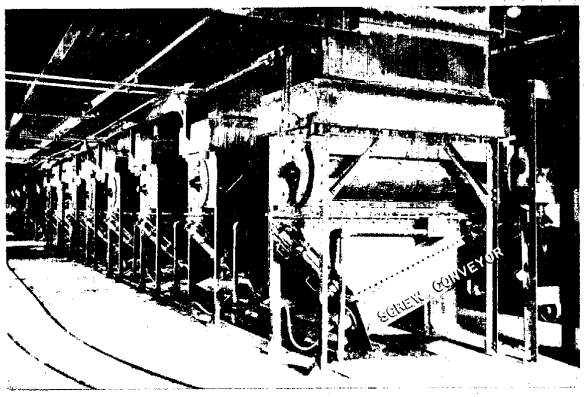


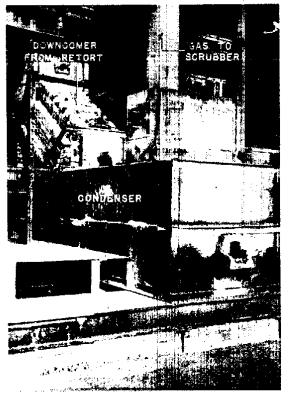
DIAGRAM OF A VERTICAL RETORT



CHARGING FLOOR OF RETORT BUILDING



DISCHARGE END OF RETORTS



CONDENSER

CASTING ROOM OF REFINERY

The spent briquets are removed from the base of the retort by means of a screw conveyor which delivers them to slag cars. While in most cases this material is disposed of at a slag dump, if it has a high lead or precious metal content it will be shipped to other metallurgical plants for further treatment.

CONDENSATION

The equipment employed to condense the vaporized zinc consists of two parts which are operated under different thermal conditions. The first part of the condenser, a conduit connected directly to the zinc-vapor orifice of the retort, is so designed that the gases are rapidly cooled. The second portion consists of a sump in which the molten metal is collected and in which the cooling and condensation of the zinc vapor are completed at a relatively slow rate.

Remnants of zinc vapor that escape condensation are recovered by passing the exhaust gases from the condenser through a scrubber. This residual zinc is collected from the scrubbing water in the form of zinc dust and may be marketed as such or recharged into the retort. The zinc-free exhaust gases, consisting primarily of carbon monoxide, can be used as fuel.

CASTING.

As the molten metal accumulates in the condenser sumps it is tapped into a large kettle from which it is ladled out and poured into molds. When cool, the slabs are removed from the molds and may be sold to consumers or remelted and refined to get a product of 99.99% purity.

DISTINGUISHING FEATURES OF VERTICAL RETORT PLANTS

Vertical retort plants have the same general appearance as horizontal retort plants. The only major differences being in the size of the charge mixing building and the size, shape, and number of retort buildings. The mixing building of a vertical retort plant will be much larger than the corresponding building at a horizontal retort plant since the furnace charge must be more carefully prepared and mixed. Instead of the 4 or more furnace buildings found at horizontal retort plants all ore is smelted in a single furnace building at plants employing vertical retorts. While

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the vertical retort furnace building is unlike horizontal retort furnace buildings in appearance it is similar in that it also emits the characteristic dense white smoke.

Another point of distinction between the two types of zinc smelters is the absence of a pottery plant which usually forms a conspicuous part of horizontal retort plants.

Vertical retort plants tend to exemplify the principles of rational arrangement which are suggested by the technical requirements of the process and economy of operation. Thus the sequence of operations (crushing, roasting, charge mixing, and finally reduction of the ore) is usually reflected in the arrangment of the buildings comprising the plant.

DISTINGUISHING FEATURES OF INDIVIDUAL STRUCTURES

Listed below are the component units of a vertical retort plant and the characteristics that are typical of them.

Ore storage building.
- Gable roof building of moderate height.
- Ore stock piles nearby.
- Ore car tracks enter or come alongside building.
- Conveyors or larry cars transport ore from this building to the roaster building.
- Building contents: Ore bins, crushers and screens.

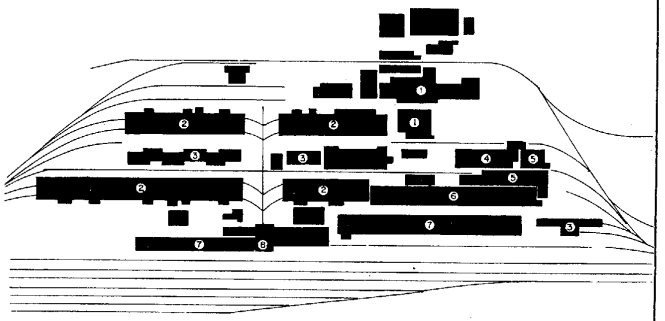
Roaster building.
- Very high building with gable roof.
- Commonly continuous monitor on roof.
- Roaster ore is carried by conveyors or larry cars to sintering building or to mixing building it sintering not carried on.
- Large flue leading from roasters to main stack or to sulfuric acid plant if present.
- Building contents: Roasters, ore hoisting equipment, and often Cottrell treaters.

Sintering building.
- Narrow gable roof building of about the same height as the roaster building.
- Commonly continuous monitor on roof.
- Near and sometimes adjoins roaster building.
- Conveyors or larry cars take sintered ore to mixing building.
- Flue carries sintering machine gases to main stack or to sulfuric acid plant if present.
- Building contents: Sintering machines, ore hoisting equipment, crushers, and mixing machines.
- Note: Sintering may not be employed at all plants; some plants only roast ore.

STEREO VIEW OF VERTICAL RETORT ZINC SMELTER - MAP BELOW

1. POTTERY PLANT
2. HORIZONTAL RETORT FURNACE BUILDINGS
3. GAS PRODUCERS
4. CHARGE MIXING FOR VERTICAL RETORTS
5. REFINERY
6. VERTICAL RETORT FURNACE BUILDING
7. ORE STORAGE
8. CHARGE MIXING FOR HORIZONTAL RETORTS

Note: This plant uses a special oxide ore which does not require roasting or sintering.



Mixing house.
- One of the largest plant buildings in floor area.
- Gable roof building of moderate height.
- Nearly square in plan
- Ore cars or conveyors take mixed charge to retort furnace building.
- Building contents: Crushers, mixers, binder tanks, ore and coal hoisting equipment.

Vertical retort furnace building.
- Very high, narrow, gable roof building.
- Must be at least 60' high to accommodate retorts.
- Continuous monitor on roof.
- Two or more stacks which emit dense white smoke.
- Building contents: Vertical retorts, briquetting machines, coking furnaces, casting equipment, and sometimes gas producers.

Casting and Refining building.
- Moderately high pitched roof building.
- Usually built as a small addition to the retort furnace building.
- Numerous small stacks on roof.
- Building contents: Fraction distillation and condensation columns, melting pots, and casting equipment.
- Note: This building not always present; some plants ship unrefined metal.

Gas Producer building.
- High, narrow, gable roof building.
- Usually has monitor on roof.
- Large gas mains leave the producer building and enter retort building and other points of gas consumption.
- Commonly some steam expelled by gas producers.
- Coal pile usually nearby.
- Building contents: Coal bins, hoisting equipment, and gas producers.
- Note: Gas producer building not always present; gas producer may be located in retort building or natural gas may be used.

Auxiliary Buildings.
- Auxiliary buildings include offices, shops, change houses, substations, laboratories and sometimes a cadmium plant.

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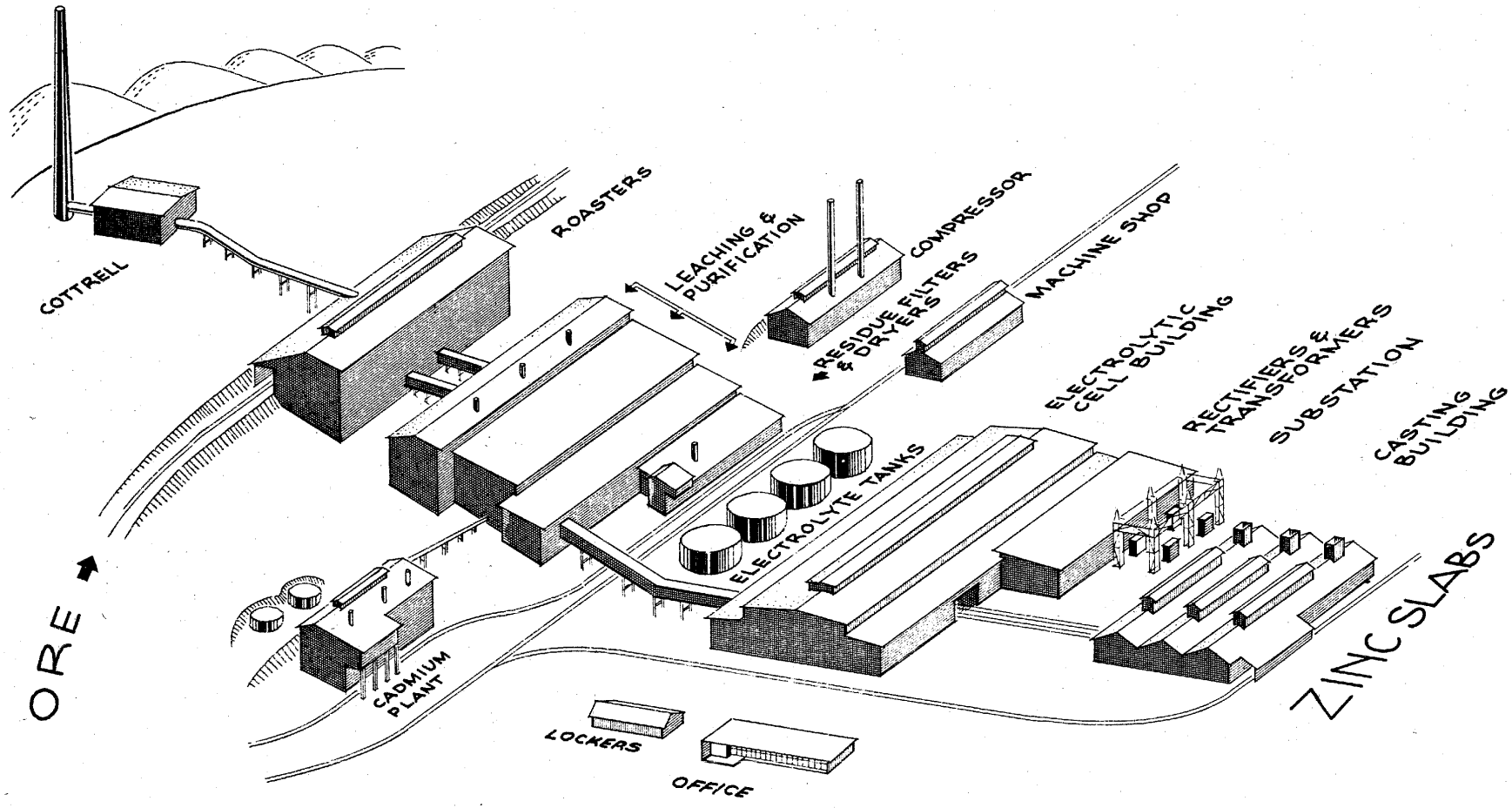
TYPICAL **ELECTROLYTIC ZINC PLANT**



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ELECTROLYTIC PROCESS

In this process, the zinc content of the roasted ore is "leached" out with dilute sulphuric acid. The zinc-bearing solution is then filtered and purified and the zinc recovered from the solution by electrolysis. The current passing through the electrolytic cell deposits the metallic zinc on the cathodes or negative poles, from which it is stripped at regular intervals, melted, and cast into slabs.

A more detailed description of the steps and equipment involved is given below.

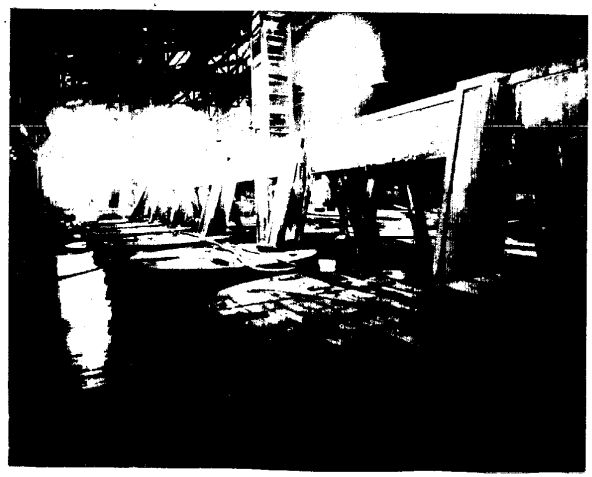
ROASTING

The concentrated ores are roasted to drive off sulfur, converting the zinc sulphide to zinc oxide. This operation and the machinery employed has been fully described in treating the horizontal retort process.

LEACHING

The object of leaching is to take the zinc content of the ore into solution. This is effected by mixing the roasted ore with the spent solution returning from electrolytic cells. The sulfuric acid strength of this returning solution varies from 10 to 23 per cent depending on the process employed. After thorough agitation essentially all of the zinc oxide is dissolved by the acid resulting in a nearly neutral zinc sulfate solution. This reaction may be represented by the chemical equation, $Zn\ O + H_2SO_4 = Zn\ SO_4 + H_2O$.

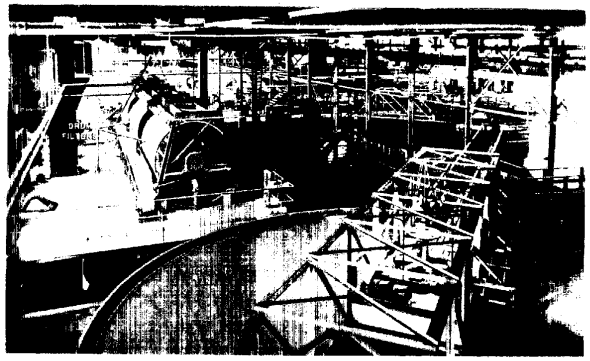
TOP OF LEACHING TANKS



The leaching operation is carried on in Pachuca tanks or similar equipment. Pachuca tanks are wood stave cylinders, 10 to 20' in diameter and 10' to 25' in height, lined with sheet lead and acid proof brick. Agitation is supplied by means of mechanically rotated wooden paddles or by a stream of compressed air.

THICKENING AND FILTERING

The leached mixture is now run into large settling tanks, called "thickeners", where the solids drop to the bottom leaving a relatively clean zinc sulfate solution. The mud removed from the bottom of the thickeners, is freed from its associated liquid by filtering in pressure or vacuum type drum filters. After filtering the solids are given a second leaching in Pachuca tanks to remove any remaining soluble zinc and are then dried and shipped to lead smelters where they are treated for the recovery of lead, silver and gold.



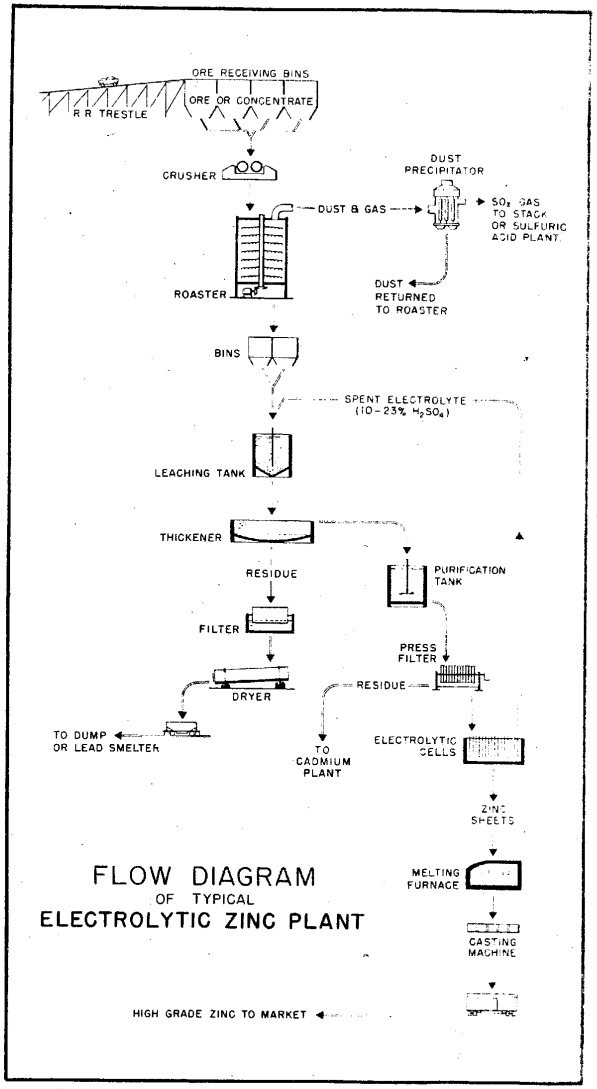
INTERIOR OF THICKENING AND FILTERING ROOM

PURIFICATION

The zinc sulphate solution coming from the thickeners and filters contains, in addition to the dissolved zinc, a number of impurities, chief among them being cadmium, copper, cobalt, antimony and arsenic.

In the purifying tanks, the solution is heated up to about 90 degrees C by steam coils and just enough zinc dust is thrown in to bring down the copper. In order to affect a more complete and speedy precipitation of impurities, agitation is supplied by agitators resembling those used in the leaching step. This charge is then filtered through Shriver filter presses or similar equipment and the filtrate is again treated with zinc dust to remove remaining impurities. Filtering and purification continues until analysis shows the solution to be of sufficient purity to enter the electrolytic cells.

The residue from the purification contains copper and cadmium in commercial quantities and is usually sent to copper and cadmium recovery plants. In general the cadmium plant duplicates in miniature the purification and electrolytic equipment of the zinc plant.



FLOW DIAGRAM
OF TYPICAL
ELECTROLYTIC ZINC PLANT

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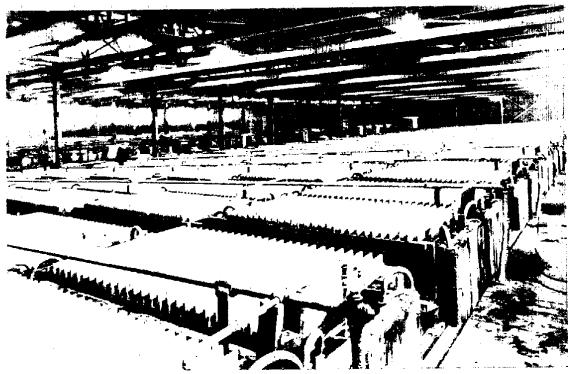
ZINC METALLURGY

ELECTROLYTIC PROCESS

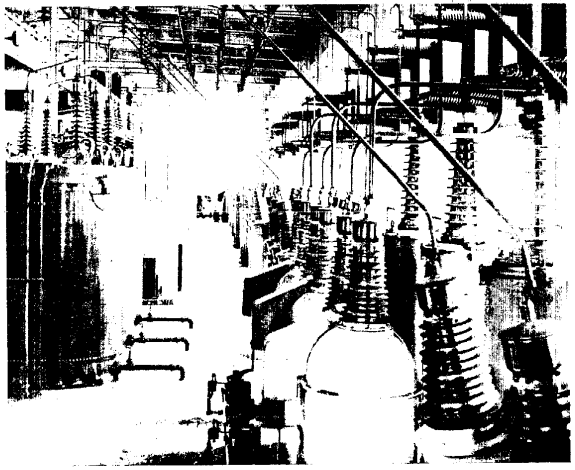
ELECTROLYSIS

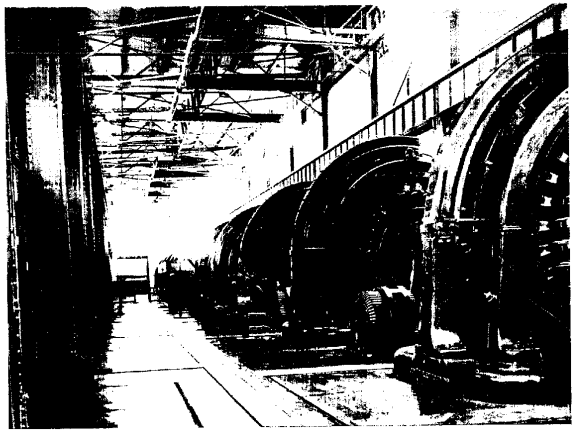
To obtain metallic zinc the purified zinc sulfate solution is pumped through electrolytic cells where it is electrolyzed with direct current between lead anodes and aluminum cathodes. These cells, each containing from 12 to 36 anodes and a like number of cathodes, are boxlike concrete or leadlined wooden tanks about 8' long, 2½' wide, and 4' deep. Hundreds of cells are required; large plants operate more than 1000.

Most plants receive their supply of electrical energy in the form of alternating current of high voltage. Hence, transformers and rectifiers are needed to convert the power into low voltage direct current. To produce one ton of pure electrolytic zinc, approximately 3500 KWH are required.



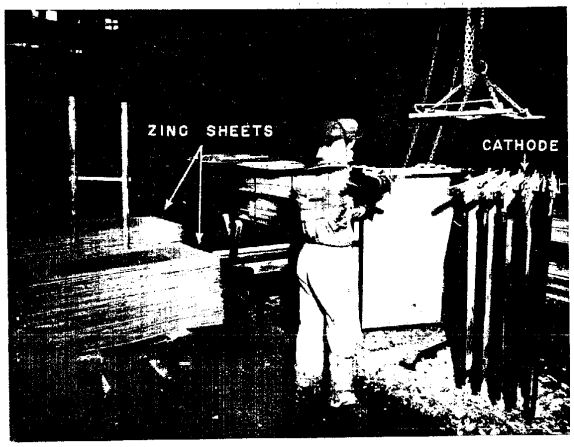
ELECTROLYTIC CELL ROOM





ROTARY CONVERTERS IN ELECTROLYTIC PLANT SUBSTATION

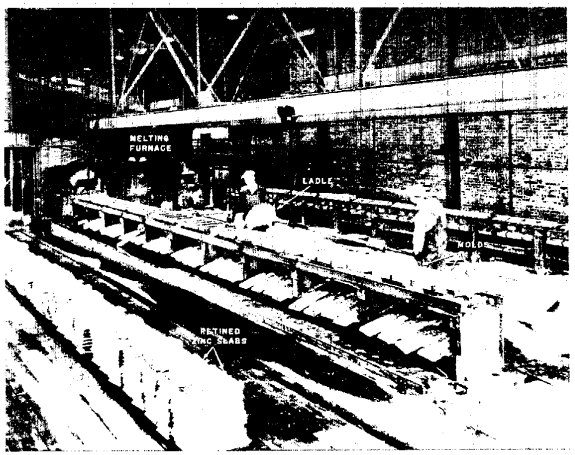
As the electrolysis proceeds metallic zinc is deposited on the cathodes and as a corollary the solution becomes increasingly acidic. At the termination of electrolysis the solution contains from 10 to 23 per cent sulfuric acid and is pumped back to the leaching tanks. The sheets of zinc deposited on the cathodes are periodically stripped off and sent to the casting house.



STRIPPING ZINC SHEETS FROM CATHODES

CASTING.

The zinc sheets are melted in small reverberatory type furnaces and cast into commercial shapes, usually 50 lb. slabs. These slabs, the final product of the electrolytic reduction process, are high grade zinc of 99.99 per cent purity.



CASTING ELECTROLYTIC ZINC

DISTINGUISHING FEATURES OF ELECTROLYTIC ZINC PLANTS

Electrolytic zinc plants differ radically from horizontal and vertical retort plants in the metallurgical principles involved and therefore it is natural that their appearances are markedly dissimilar. Not only are the size, shape, and arrangement of the buildings different but the dense white smoke, one of the outstanding recognition features of horizontal and vertical retort furnace buildings, is absent at electrolytic plants. The only large volume of smoke emitted at electrolytic plants is that expelled by the main stack which is primarily roaster dust. Items that are common to most electrolytic plants and which will aid in identifying them are listed below.

(1) Located in areas where cheap hydro-electric power is available.
(2) Usually built on a side hill to take advantage of gravity flow.
(3) Located along a railroad and often along navigable body of water.
(4) Ore cars or ore bargesin vicinity of plant.
(5) Ore piles which are light to dark brown in color.
(6) Waste ponds, if present, are light in color.
(7) Nearly always a stack at least 200' high. Plants which send their roaster gases to a sulfuric acid plant may or may not have this stack.
(8) Usually several large tanks between leaching building and electrolytic building.

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DISTINGUISHING FEATURES OF INDIVIDUAL STRUCTURES.

Since in this process large volumes of solution are handled, the plant is so arranged that the ore enters the plant at its highest elevation and the subsequent operations are carried on at successively lower elevations with the finished metal emerging at the plants lowest elevation. Thus the relative elevation of the various buildings is a key to their identification.

Listed below are the buildings comprising an electrolytic plant and the features that distinguish them.

Ore storage building.

Gable roof building of moderate height.

Ore stockpiles nearby.

Ore cars enter or come alongside this building.

Conveyors or larry cars transport ore from this building to the roaster building.

Building contents: Ore bins, crushers, and screens.

Note: At some plants the ore is stored and crushed in the roaster building.

Roaster building.

Very high building with gable roof.

Commonly continuous monitor on roof.

Roasted ore is moved by conveyors or larry cars to to leaching building or to sintering building if present.

Large flue leading from roasters to main stack or to sulfuric acid plant if present.

Building contents: Roasters, ore hoisting equipment, and often ore bins and crushers.

Leaching and Purification building.

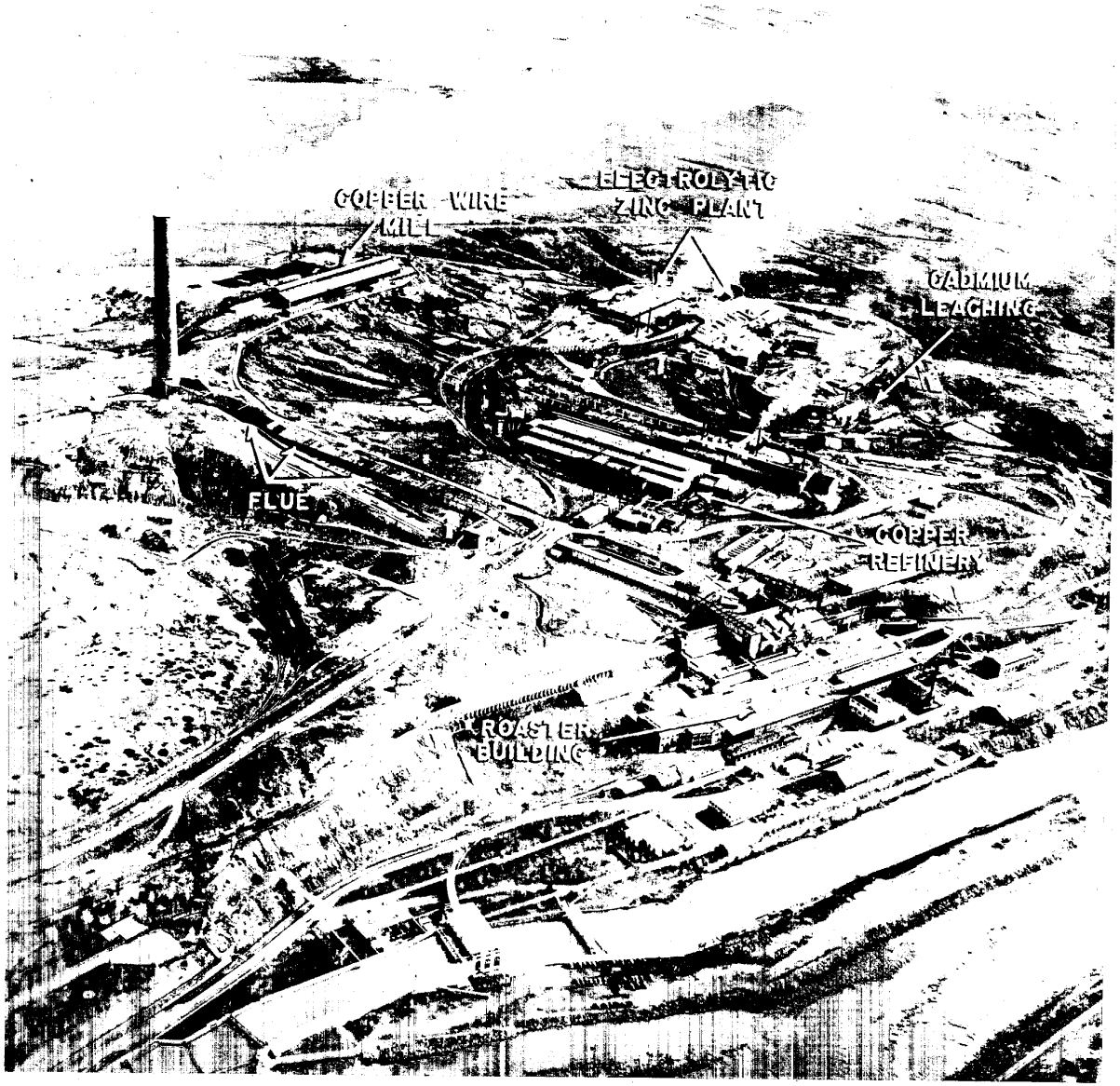
Large stepped roof building located below roasting or sintering building.

Building of moderate height.

Leaching equipment in upper section; purification equipment in lower section.

Commonly several small stacks protrude from leaching section.

Large pipes carry the zinc pregnant solution from this building to the electrolytic cell building or to electrolyte tanks.



Building contents: Leaching tanks, thickeners, filters, purification tanks, pumps, and ore handling equipment.

Residue treatment building.

Usually adjoins the lower side of the leaching and purification building.

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ZINC METALLURGY

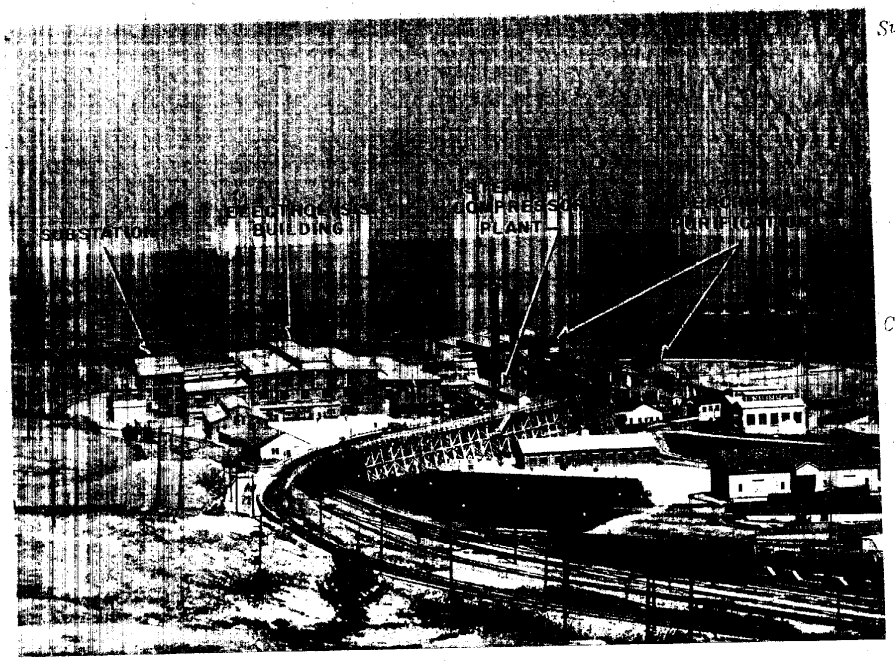
DISTINGUISHING FEATURES OF ELECTROLYTIC PLANTS

Medium in size and height.

Commonly several short stacks.

Charging elevator feeds residue into ore cars.

Building contents: Filters, drying kilns, and residue bins.



Electrolytic cell building.

Very large building with low pitch roof.

Normally at lower elevation than the leaching and purification building.

Commonly several large electrolyte tanks between leaching and electrolytic cell building.

Power lines enter from substation.

Connected to casting building by narrow gage tracks.

Building contents: Pumps, electrolytic cells, and cathode stripping equipment.

Casting building.

Monitor gable roof building of moderate size.

Continuous monitors on roof.

Short stacks for expulsion of melting furnace gases.

Located adjacent to electrolytic cell building.

Loading platform for shipping slab zinc.

Building contents: Melting furnaces, ladles and molds.

Substation

Usually adjoins electrolytic building.

Building of moderate height with low pitch roof.

Transformer yard outside.

Building contents: Transformers, rectifiers, converters and control panel.

Cadmium plant.

Cadmium Leaching building usually of moderate height with gable roof.

Conveyor or larry cars bring cadmium-rich precipitate from main purification building to cadmium leaching building.

Charging elevator feeds residue into ore cars.

Usually several small tanks on uphill side of building.

Electrolysis may take place in this building or in a section of main electrolytic building.

Casting may take place in same building or in small casting building nearby.

Building contents: Leaching tanks, filters, and sometimes electrolytic cells and casting equipment.

Steam and Compressor plant.

Usually located in vicinity of leaching building.

Building of moderate size and height with gable roof.

Often has continuous monitor on roof.

Two or more tall slim stacks to expel boiler gases.

Usually coal pile nearby.

Building contents: Steam boilers and air compressors.

Auxiliary Buildings.

In addition to the buildings listed above electrolytic zinc plants have the standard auxiliary buildings such as offices, laboratories, assay offices, shops, and change houses.

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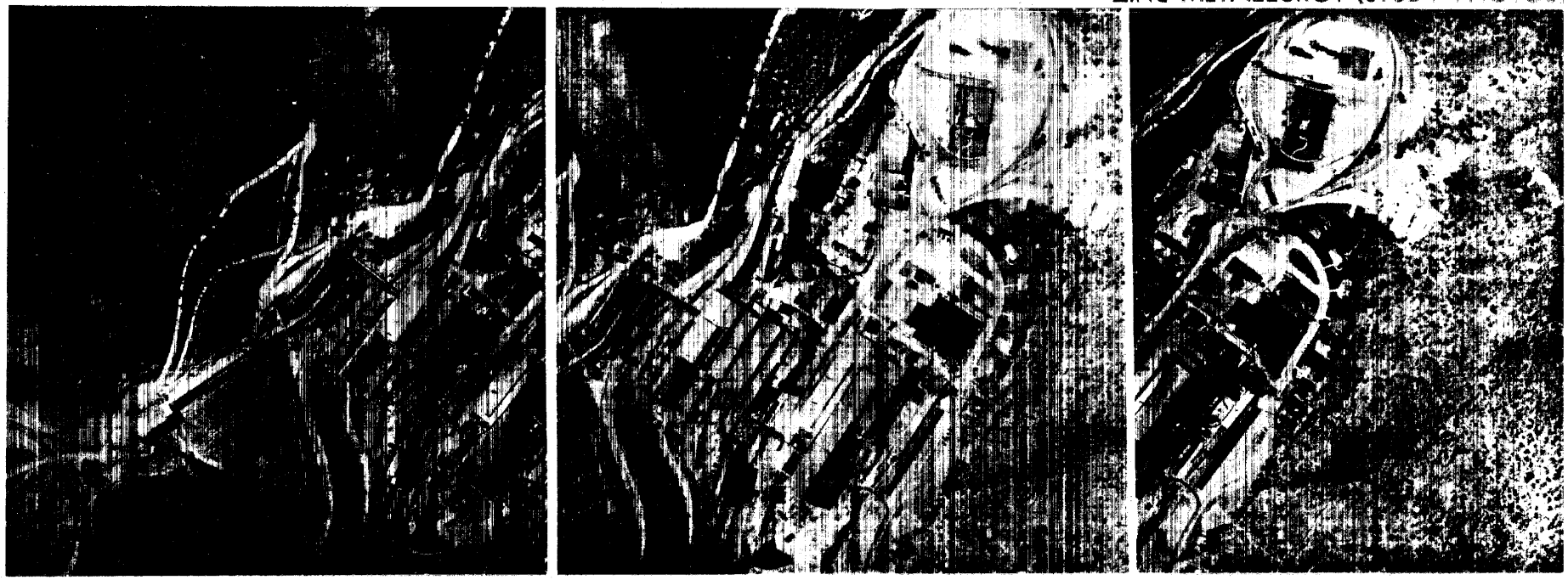
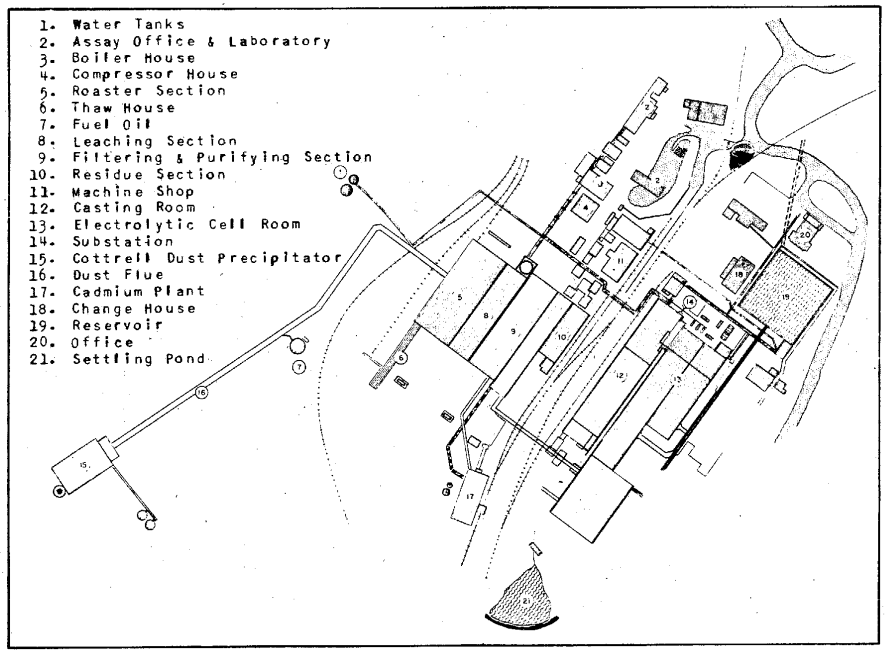
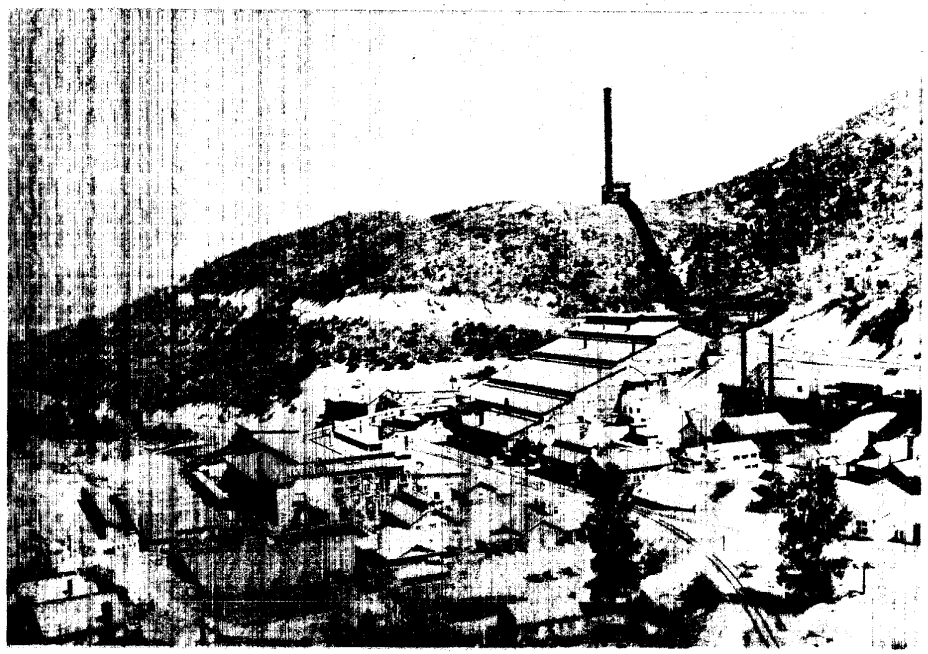


STEREO AND OBLIQUE VIEWS OF ELECTROLYTIC ZINC PLANT AT KELLOG





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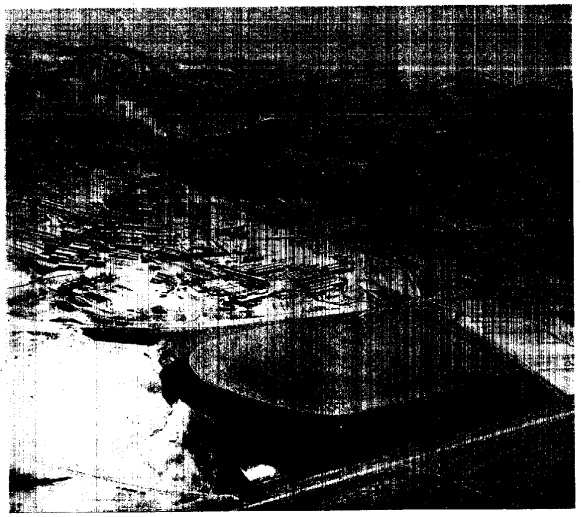
ZINC METALLURGY (STUDY PHOTOS)



GREAT FALLS ELECTROLYTIC ZINC PLANT
AND COPPER REFINERY

1. MAIN OFFICE
2. SHOPS
3. ROASTER BUILDING
4. THAW HOUSE
5. ORE BINS
6. COTTRELL DUST COLLECTOR
7. FLUE
8. ELECTROLYTIC COPPER REFINERY
9. COPPER CASTING
10. FUEL TANKS
11. CADMIUM LEACHING
12. ZINC STORAGE YARD
13. RESIDUE DRYING
14. FILTERING AND PURIFYING
15. ZINC LEACHING
16. ZINC OXIDE BAGHOUSE
17. ZINC CASTING
18. ELECTROLYTE TANKS
19. ELECTROLYTIC CELL ROOM
20. SUBSTATION
21. STEAM PLANT
22. CHANGE HOUSE
23. COPPER WIRE MILL

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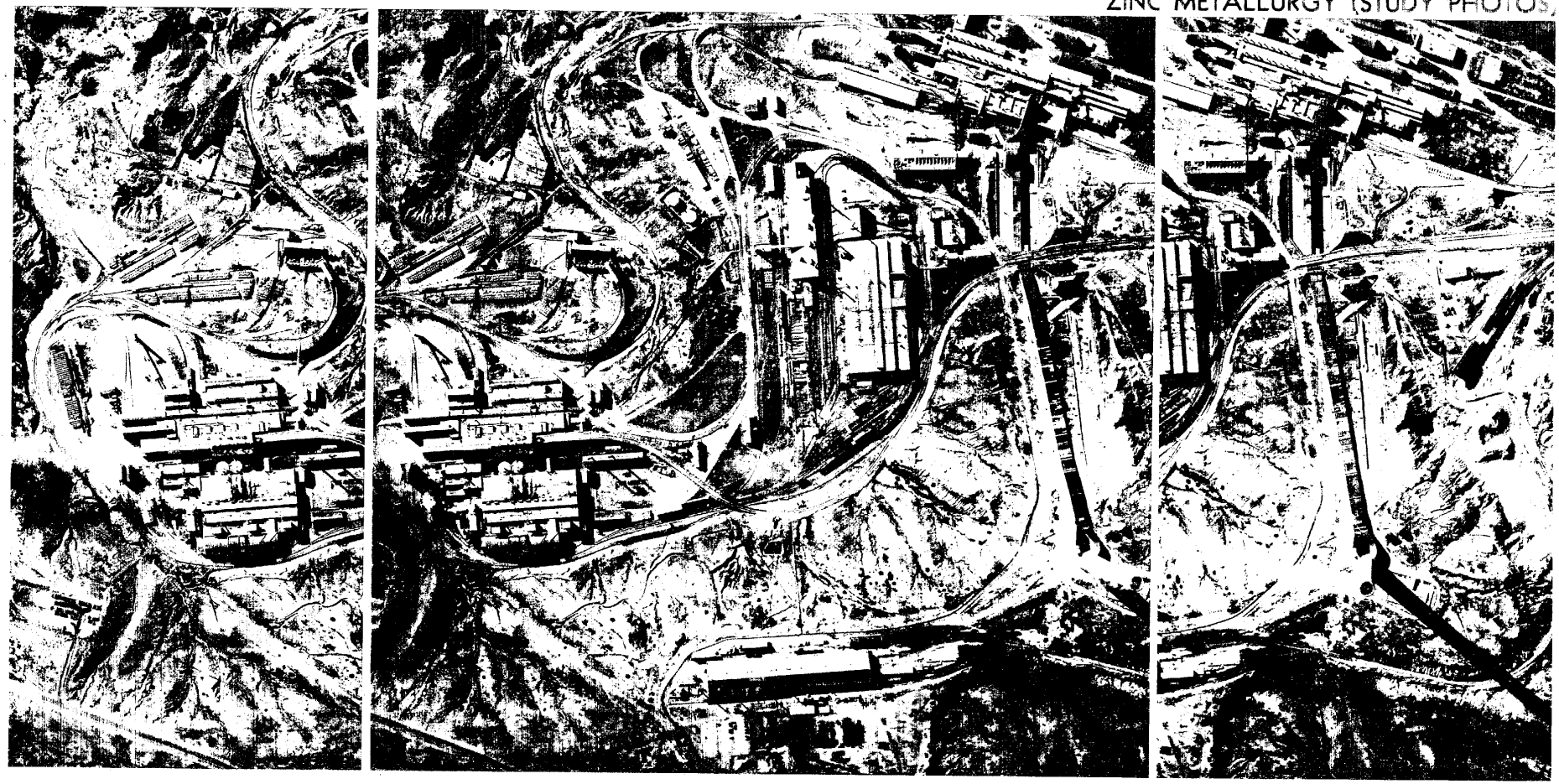

GREAT FALLS ELECTROLYTIC ZINC PLANT AND COPPER REFINERY

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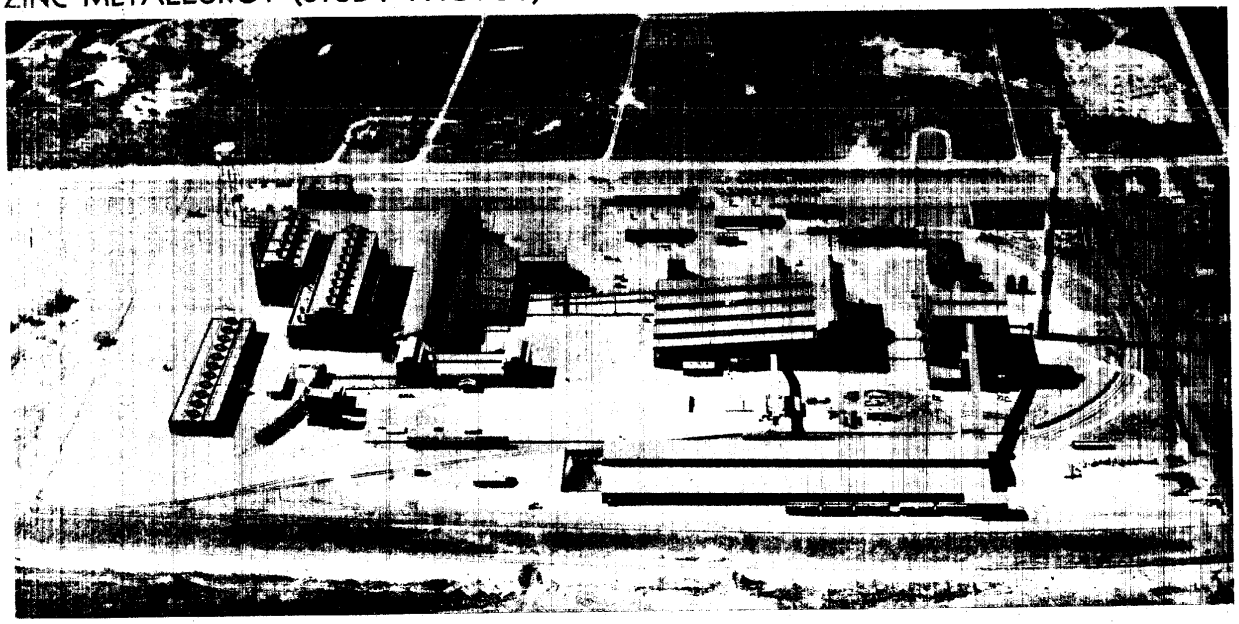
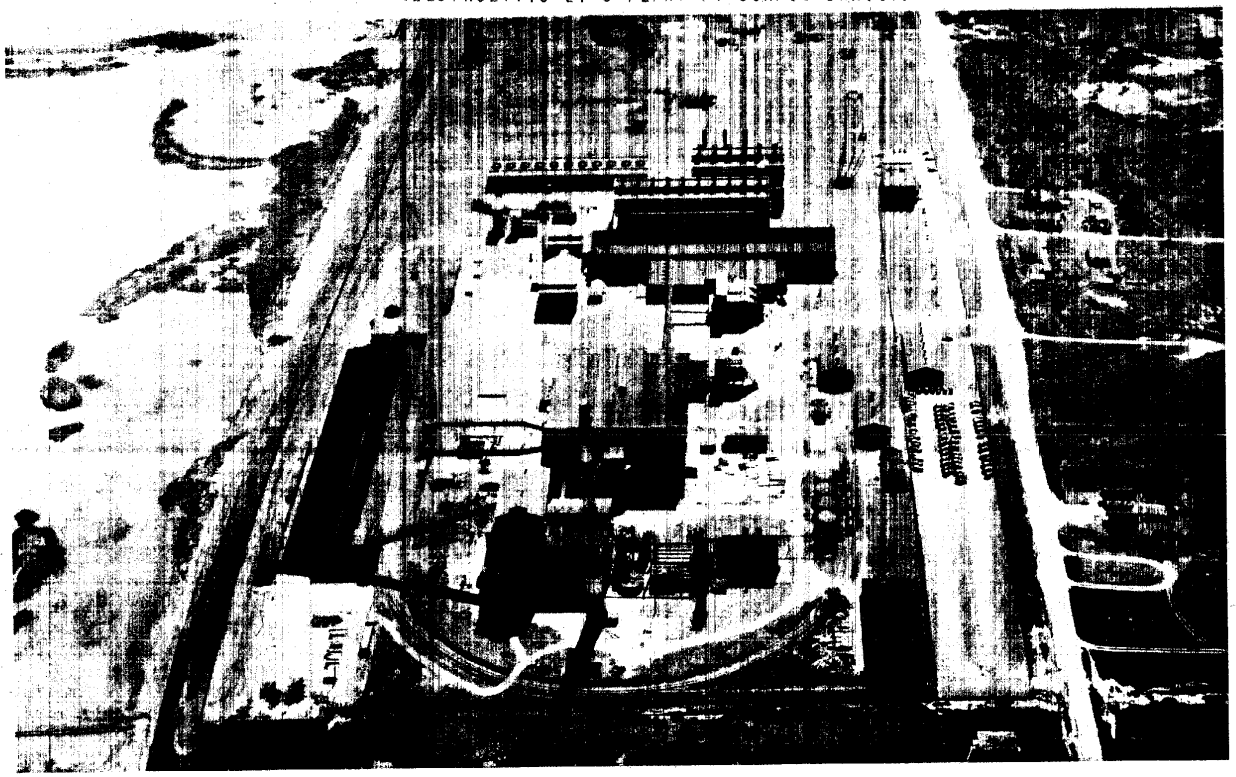
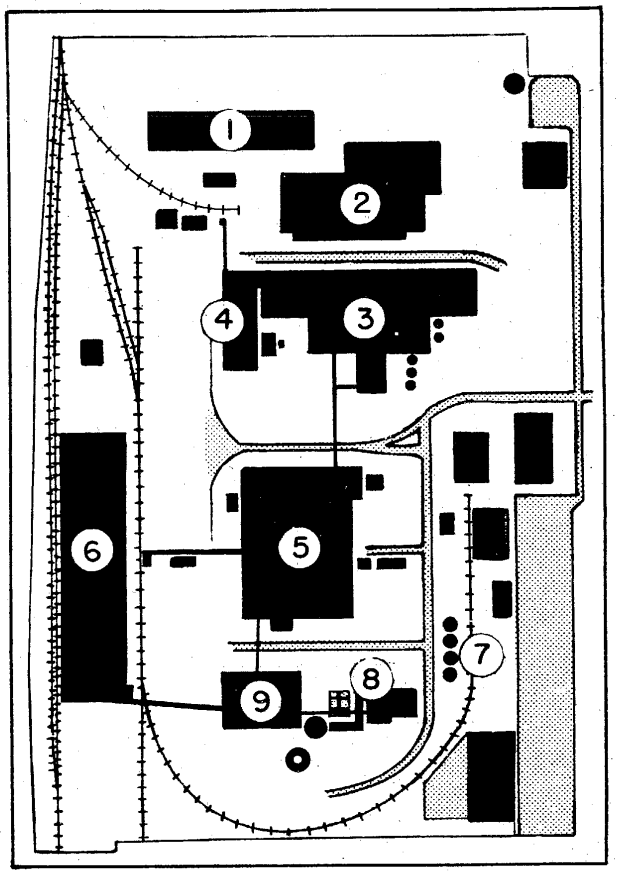
ZINC METALLURGY (STUDY PHOTOS)



ELECTROLYTIC ZINC PLANT AT CORPUS CHRISTI





1. BOILER HOUSE
2. TURBINE & GENERATOR HOUSE
3. ELECTROLYTIC CELL ROOM
4. CASTING SHED
5. LEACHING & PURIFYING
6. ORE STORAGE
7. SULFURIC ACID TANKS
8. SULFURIC ACID PLANT (CONTACT PROCESS)
9. ROASTER BUILDING

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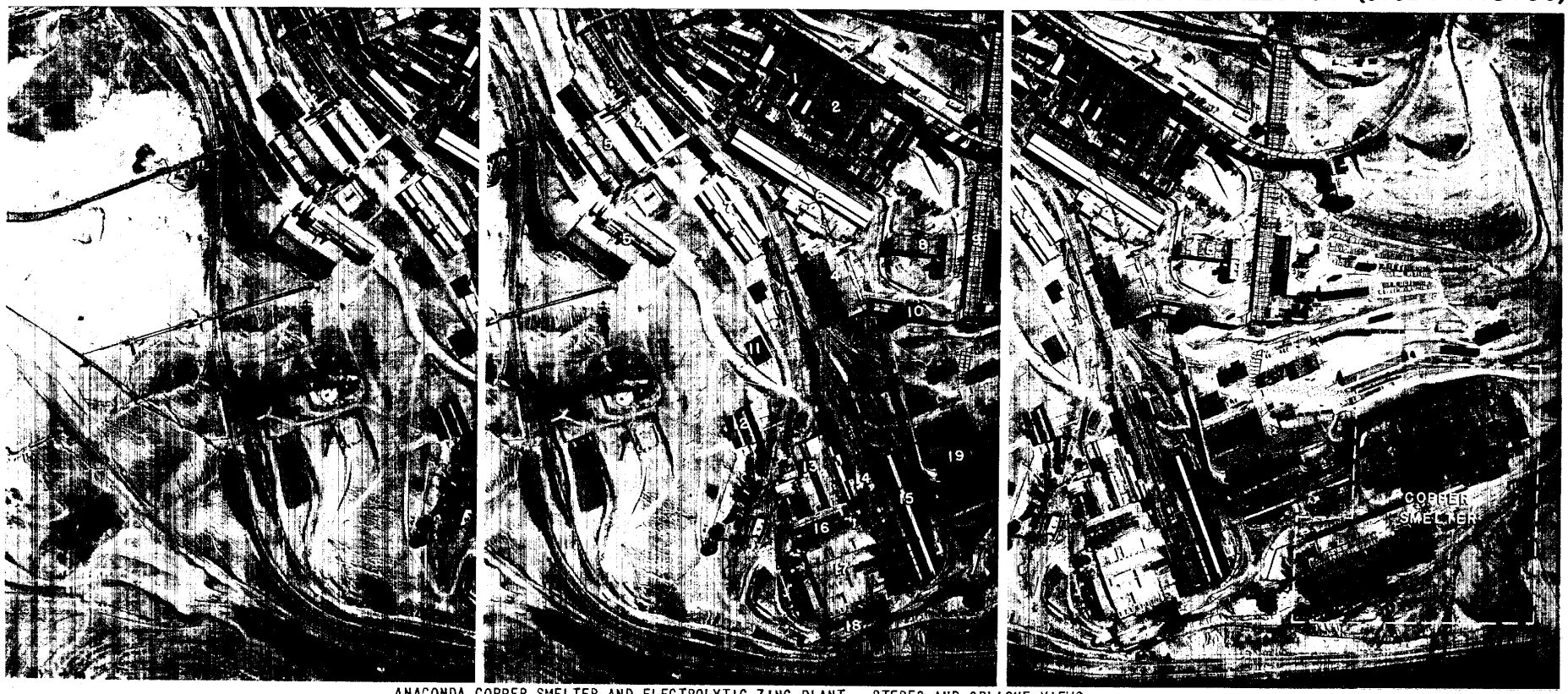
ZINC METALLURGY (STUDY PHOTOS)



ANACONDA COPPER SMELTER AND ELECTROLYTIC ZINC PLANT - STEREO AND OBLIQUE VIEWS

1. CONCENTRATORS
2. POWER HOUSE
3. TAILINGS STORAGE
4. ROASTER BUILDINGS
5. BY-PRODUCT PLANTS - PHOSPHATES
6. DORR THICKENER PLANT
7. FLOTATION PLANT
8. SUBSTATION
9. DUST FLUE
10. COTTRELL DUST PRECIPITATOR
11. LABORATORY
12. ZINC PURIFICATION BUILDING
13. ZINC LEACHING BUILDING
14. ZINC ORE STORAGE
15. POWER HOUSE
16. SUBSTATION
17. ELECTROLYTIC CELL ROOM
18. ZINC CASTING ROOM
19. ROASTER BUILDING

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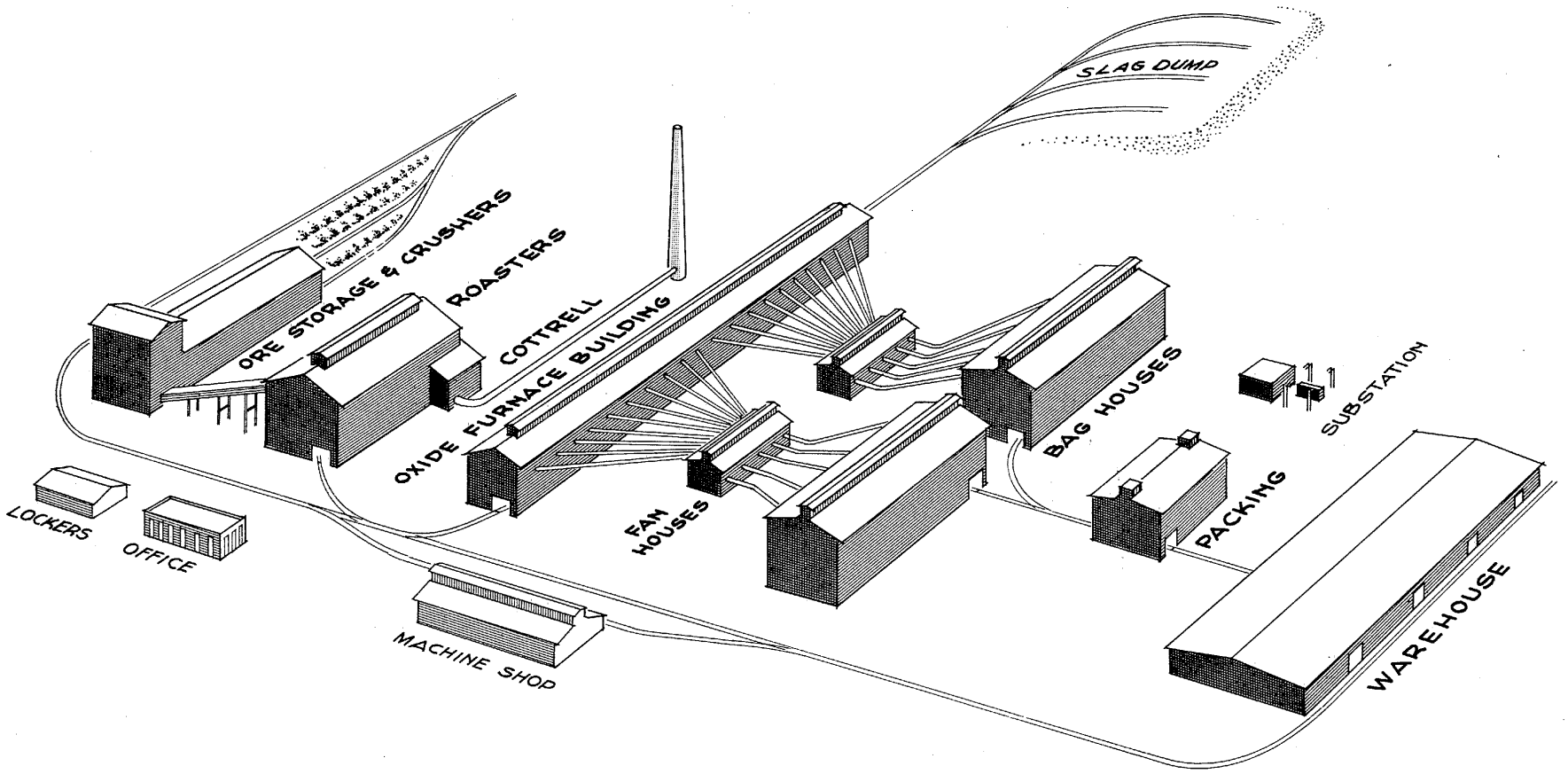
TYPICAL ZINC OXIDE PLANT (AMERICAN PROCESS)



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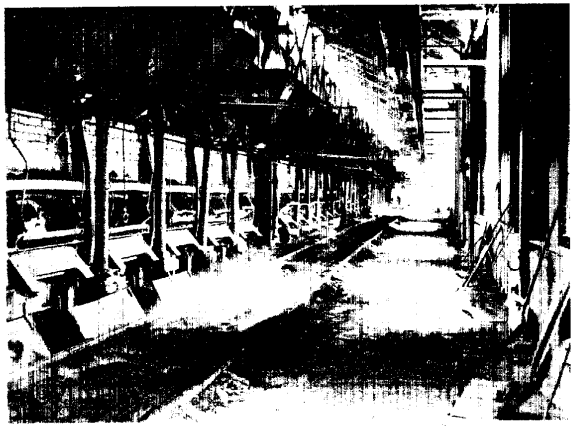
ZINC OXIDE

Zinc Oxide is a white, snowy, metallic pigment, in all appearances resembling household white flour. It is formed by vaporizing zinc, either directly from the ore or "indirectly" from slab zinc and allowing this vapor to come in contact with an oxidizing atmosphere. The vaporous zinc burns in air with an intense flame, producing zinc oxide. In commercial plants, the zinc oxide laden air is drawn through cooling flues and the pigment is caught in the meshes of muslin or woolen bags. The manufacture of zinc oxide directly from the ore is known as the "American Process" and the manufacture of zinc oxide from slab zinc is known as the "French Process." Both processes are described below.

AMERICAN PROCESS

Sulphide ores arriving at the plant must first be roasted prior to charging into the furnace; oxide ores, on the other hand, are mixed with coal and fed directly into the furnace.

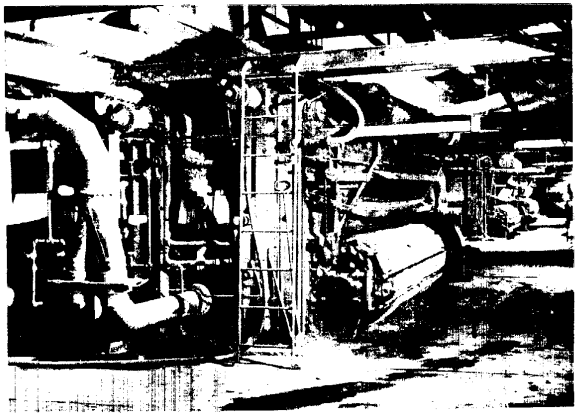
There are several types of manually operated furnaces differing slightly in construction details. One common type 45' long, 16' wide, and 7' high is built of fire-



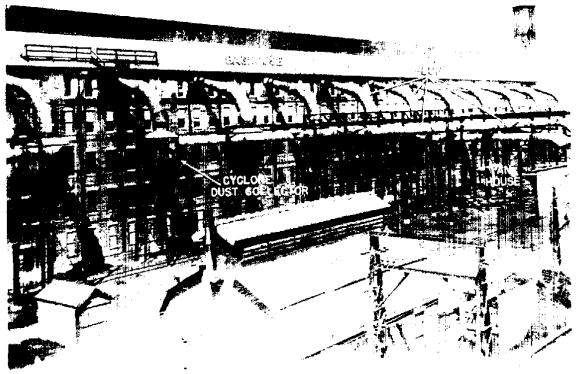
ROW OF MANUALLY OPERATED FURNACES

brick and masonry strengthened by steel rods. The charge is dropped through openings in the roof onto a fire grate which is covered with burning coal. The zinc vapor produced by the heat and reducing action of the burning coal combines with air in the upper part of the furnace and burns to zinc oxide. At the termination of the reduction period the residue is raked off the grate and discarded.

A newer continuous mechanical furnace is also being used in some plants. This furnace employs an endless traveling grate which carries the charge through a combustion chamber where the ore is reduced and the resultant zinc vaporized and oxidized. The residue passes off at the tail end of the grate into cars which carry it to the slag dump.

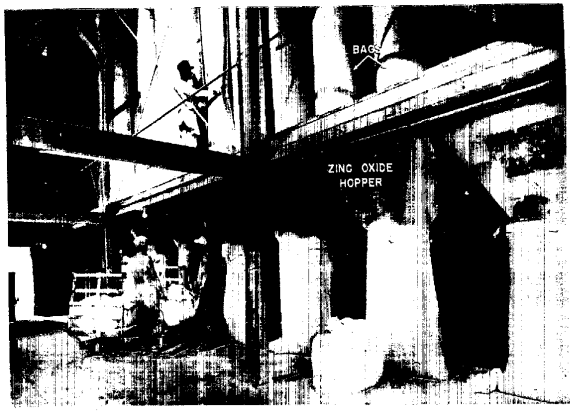


MECHANICAL ZINC OXIDE FURNACES

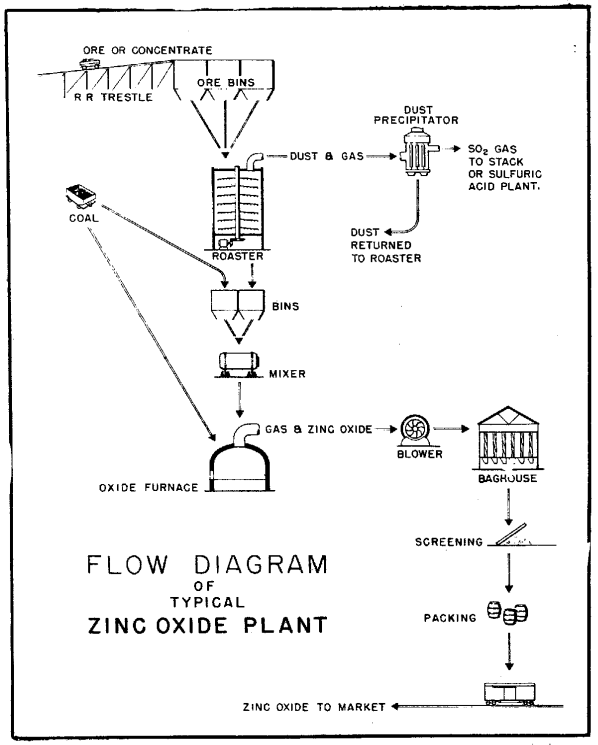


EXTERIOR OF BAGHOUSE

Electrically driven fans draw the zinc oxide and combustion gases from the furnaces and force them through a system of large sheet-iron cooling flues into a baghouse. The main flues entering the baghouse are tapped by numerous feeder flues which transport the oxide bearing gases to vertically hung muslin or woolen bags. The bags, which may be as large as 30" in diameter and 45' long, filter the gas, leaving a coating of zinc oxide adhering to the cloth. Periodically the bags are shaken, the oxide dropping into hoppers at the base of the bags. The oxide collected in the hoppers is sent to the packing house where it is sampled, graded and mixed with other batches to make a standard product. Bolting machines, similar to flour bolting machines, pick out any pieces of foreign matter such as bits of metal, bag strings, etc. The finished product is now packaged or



INTERIOR OF BAGHOUSE



FLOW DIAGRAM
OF
TYPICAL
ZINC OXIDE PLANT

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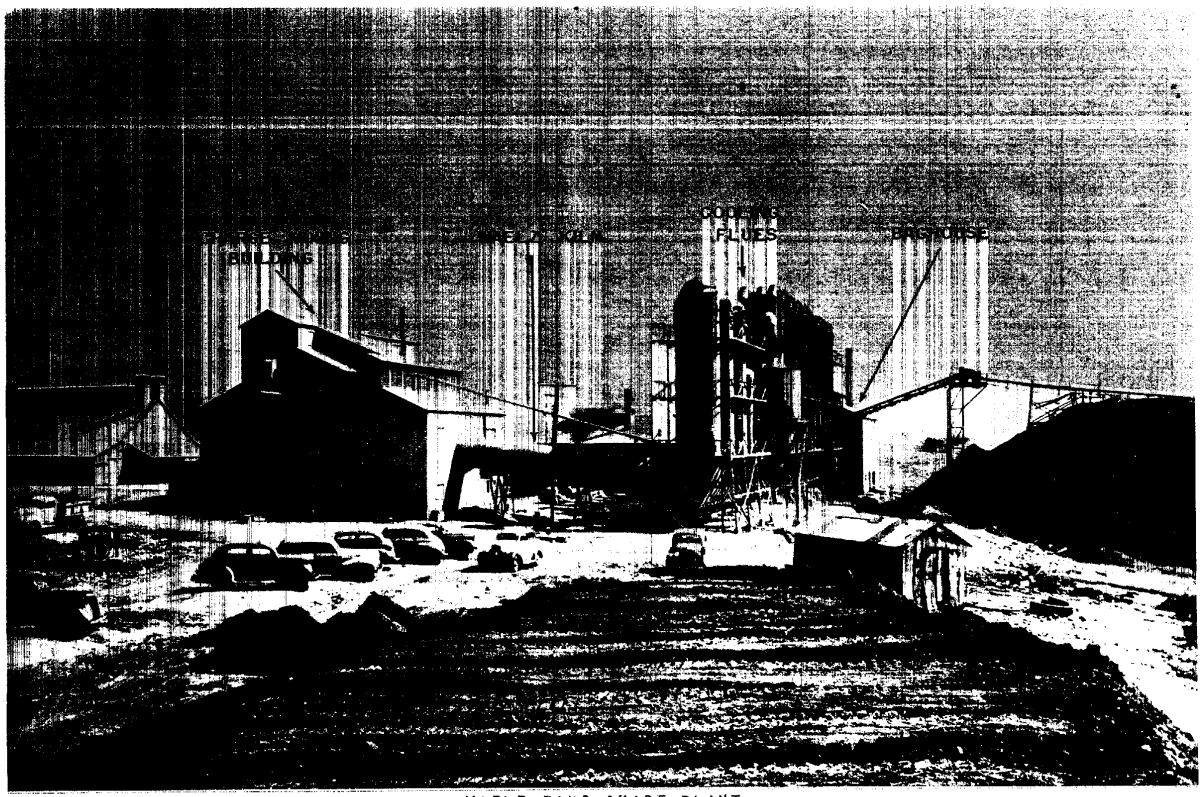

WAELZ ZINC OXIDE PLANT

barreled and shipped to consumers.

FRENCH PROCESS

French Process zinc oxide, a much purer product than the oxide produced by the American process, is manufactured by vaporizing slab zinc in an oxidizing atmosphere.

The furnace used resembles a horizontal retort zinc furnace, as it also has a recuperating pre-heating base and a laboratory in which are suspended a row of retorts very similar to those of the horizontal retort furnace. Slabs of zinc are chopped or broken up into convenient sizes and placed in the retort through its open end at the rear of the furnace. Before sealing the end with clay, a pipe carrying a stream of carbon monoxide gas is inserted in the retort. The stream of carbon monoxide gas serves two purposes, namely, to prevent oxidation in the retort proper and to lead the zinc vapor to the retort orifice

As the heat of the furnace, approximately 1400°C, is transmitted to the retort the zinc melts and as the temperature rises it vaporizes. The vapor flows to the front end of the retort and there it comes in contact with air and "burns" with a bright yellowish flame to zinc oxide.

The stream of zinc oxide now appearing as a dense snow floated in air, is drawn up from the furnace to the collection chamber. The collection chamber is a large oblong sheet metal compartment with baffle plates extending from both top and bottom. Larger and heavier particles of zinc oxide fall to the bottom and drop into hoppers while the lighter particles are carried to the exit. Leaving the collection chamber, the gas, still heavily laden with zinc oxide held in suspension is fed to a fan and forced into a bag house where the remaining oxide is recovered.

The zinc oxide accumulated in the hoppers of the collection chamber plus that from the baghouse is sampled, mixed, cleaned, and packaged for shipment to consumers.

OTHER PROCESSES

Materials low in zinc content such as the residue from zinc smelters, slag from lead smelters, and low grade oxide ores are sometimes treated in Waelz kilns. A Waelz kiln is a large brick-lined steel cylinder varying in length from 40' to 160' and in diameter from 6' to 12'. This long cylinder is supported at a very slight pitch from the horizontal on two or more rolled steel tires which in turn revolve on heavy friction rollers. Power to rotate the kiln is usually supplied by an electric motor.

The ore or slag is first ground and mixed with coke or coal and then fed into the higher end of the kiln. The rotation of the kiln causes the burning charge to slowly work its way to the exit end where it is discharged into cars and sent to the slag dump. During its journey through the kiln, the charge is subjected to heat produced by the burning fuel which reduces and vaporizes the zinc. The vapor thus formed is instantly oxidized and carried by flues, along with the combustion gases, to either a baghouse or Cottrell.

The zinc oxide collected by the bags or Cottrell may be sent to a zinc smelter or, if of sufficient purity, graded, cleaned and shipped to consumers.

DISTINGUISHING FEATURES OF ZINC OXIDE PLANTS

Zinc oxide plants can be distinguished from other metallurgical plants by the maze of flues which carry the oxide bearing gases from the furnace building to the baghouse. Another point of recognition is the white zinc oxide deposit that frequently stains the roofs on the baghouses. In addition to these characteristics, zinc oxide plants exhibit other features that are common to all zinc plants such as: ore piles which are light to deep brown in color; ore cars or ore barges nearby; black slag dumps; coal piles; and a stack 200' or more in height unless the roaster gases are sent to a sulfuric acid plant.

DISTINGUISHING FEATURES OF INDIVIDUAL STRUCTURES. (AMERICAN PROCESS PLANTS)

The functions of the various units comprising an oxide plant will normally be revealed by an examination of the external characteristics of the buildings, by their rail, conveyor, and flue connections and by the stock and waste piles associated with them. Zinc oxide plants, like zinc smelters, have ore storage facilities, roaster and/or sintering buildings and the standard auxiliary buildings such as offices, shops, and change houses. These buildings are not listed below, since their identifying features have been treated in the

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ZINC METALLURGY

DISTINGUISHING FEATURES OF ZINC OXIDE PLANTS

STEREO VIEW OF WEST PALMERTON ZINC OXIDE PLANT - KEY BELOW

horizontal retort plant section.

Furnace building.

Long narrow building, low to moderate in height.

Gable roof with continuous monitor.

Readily identified by the many flues leaving the building.

Narrow gage track connections to slag dump.

Building contents: Numerous oxide furnaces, charging and slag removal machines.

Fan house.

Small low building with gable roof.

Readily identified by convergence of flues from both furnace building and baghouses.

Often cyclone dust precipitators nearby.

Building contents: Electric motors and blowers.

Baghouses..

High relatively wide gable roof buildings.

Continuous monitors on roofs.

These buildings are the terminus of the flues.

Frequently roofs are stained with white zinc oxide.

Larry cars carry the oxide from baghouses to the

1. POWER PLANT
2. ORE & COAL BINS
3. FURNACE BUILDING
4. FAN HOUSES
5. MAIN OFFICE
6. BAG HOUSES
7. ZINC OXIDE PACKING
8. SHOPS
9. ZINC OXIDE STORAGE

Note: This plant uses a special oxide ore which does not require roasting or sintering.

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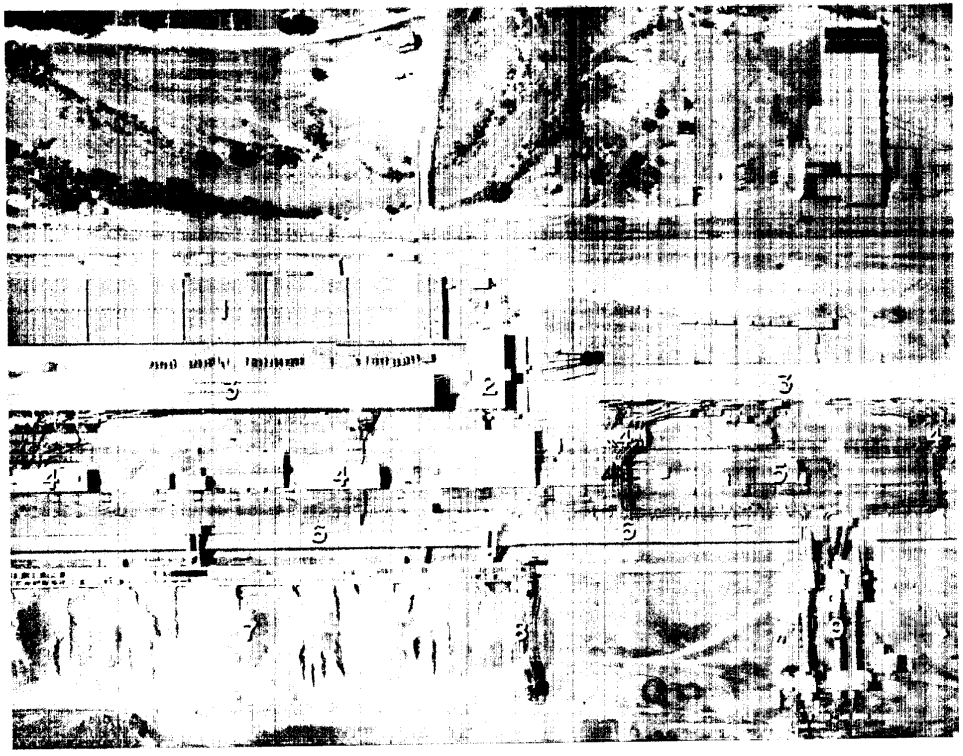
ZINC METALLURGY

DISTINGUISHING FEATURES OF ZINC OXIDE PLANTS

STEREO VIEW OF EAST PALMERTON ZINC OXIDE PLANT - KEY BELOW



1. ZINC OXIDE STORAGE
2. ZINC OXIDE PACKING
3. BAG HOUSES
4. FAN HOUSES
5. SUB STATION
6. FURNACE BUILDING
7. ORE & COAL BINS
8. GANTRY CRANE
9. WAELZ ZINC OXIDE FURNACES

Note: This plant uses a special oxide ore which does not require roasting or sintering.

packing building.

Building contents: Cotton or woolen bags and oxide hoppers.

Packing house.

Usually 2 or 3 story building of moderate size.

Ventilators on roof.

Elevators sometimes protrude from roof.

Track connections to warehouses.

Building contents: Oxide bins, screens, and packing machines.

Warehouses.

Large low buildings with low pitch roofs.

Loading platform.

Railroad tracks parallel loading platform.

DISTINGUISHING FEATURES OF OTHER TYPES OF ZINC OXIDE PLANTS

French process zinc oxide plants derive their oxide from slab zinc, not ore, and consequently ore piles, roaster buildings, and sintering buildings will not be found at plants of this type but the furnace building, blower houses, baghouses, etc., are present and will fit the description given above.

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Zinc oxide is also produced by passing the ore through a Waeltz kiln and collecting the oxide thus formed in either baghouses or Cottrell precipitators. The kilns can be easily recognized by their form if they are not enclosed. The flues carrying the oxide from the kilns can be traced through the blower house into the baghouses or Cottrell treaters.

VULNERABILITY

Zinc smelting facilities are generally considered better targets than mining and milling installations because of the following conditions: (1) the limited number of metallurgical plants upon which the enemy must rely for his zinc supply, (2) the complexity of some of the smelting and refining equipment and the difficulty of readily replacing it, (3) the short time lag between the production of refined metal and its use in alloys, galvanizing, rolled zinc, etc., and (4) the lack of dispersion of the various buildings comprising the plants. However, in the particular case of Japan where there is an acute ore shortage and an excess smelting capacity, the destruction of mines and mills may have the more serious effect on metal output.

Metallurgical plants are generally considered poor incendiary targets since most of the buildings handle incandescent matter and obviously are constructed of non-combustible materials. There are some structures and materials that will support fires such as office buildings, change houses, some shops, and oil and coal stores, but the vital smelting and refining operations are much more susceptible to damage by high explosive than by incendiary bombs.

In comparing the overall vulnerability of the various types of zinc and zinc oxide plants it is noted that the degree of vulnerability of the plant depends to a large extent on the particular process employed. For instance, vertical retort plants are much more highly mechanized than horizontal retort works and therefore can be more easily and seriously damaged. Although electrolytic zinc plants use a mechanized process, knocking out a few units will merely curtail output instead of completely halting production because these plants are characterized by a large number of identical units working in parallel. Similarly the effectiveness of damage done to zinc oxide plants will be limited, unless all of the machines doing a particular operation are destroyed.

VULNERABILITY OF INDIVIDUAL UNITS

In determining the vulnerability of the individual units comprising the metallurgical facilities the following factors are taken into consideration: (1) The degree of dependence of plant production on the particular operation under scrutiny; (2) The equipment used, its construction, and availability; (3) The length of time necessary to repair or rebuild the damaged machinery and; (4) the combustibility of building, equipment, and stored materials. These four factors are the basis for arranging the component parts of the various plants in the order shown below. The most vital units are listed first.

HORIZONTAL RETORT PLANT	VERTICAL RETORT PLANT	ELECTROLYTIC PLANT	ZINC OXIDE PLANT
Power Supply	Power Supply	Power Supply	Power Supply
Pottery Plant	Mixing Building	Roaster Building	Blower Building
Gas Producer Building (if present)	Gas Producer Building (if present)	Electrolytic Cell Building	Roaster Building
Roaster Building	Vertical Retort Building	Leaching and Purification Bldg.	Furnace Building
Horizontal Retort Building	Roaster Building	Casting Building	Baghouses
Refining and Casting Building	Refining & Casting Building	By-products Plants	By-Products Plants
By-Products Plants	By-Products Plants		

A brief discussion of the target value of each of these individual units follows.

Power Supply – As nearly all operations, particularly grinding, crushing, mixing, and ore conveying systems are mechanized with electric motors it is possible to stop all production by damaging or destroying either the primary power plant, which may be some distance from the zinc works, or the substation which is always a part of the metallurgical plant. Interruption of the power would be particularly effective in halting an electrolytic plant where zinc production is directly dependent upon a continuous supply of electricity.

Power plant boilers, turbines, and generators are expensive equipment and probably would be difficult to readily replace if destroyed. This also applies to substation equipment which includes transformers, mercury arc rectifiers, rotary converters, and control panels.

Direct hits would probably be required to destroy power plants or substations since they are generally constructed of reinforced concrete or other sturdy non-combustible materials.

Pottery Plant.

The clay condensers and retorts used in a horizontal retort plant must be continually replaced since their average lives are only 7 and 35 days respectively. Depriving the smelter new condensers and retorts would cause the cessation of all zinc production.

The clay mixing apparatus, hoisting machinery, and drying kilns are standard equipment but the mechanical presses are specially designed and could not be easily replaced. This equipment is usually housed in a building which has brick or concrete bearing walls with a steel truss roof covered by wood sheeting and roofing paper

Gas Producer Building.

In areas where natural gas is not available, the gas necessary to fire the ore drying kilns, retort furnaces, and refining furnaces is manufactured from coal. Usually, 4 or more gas producers are set up in parallel and consequently it would be necessary to knock out all producers to halt all zinc smelting. This stoppage would probably be one of short duration because gas producers are standard equipment in all industrial areas and replacements could be readily found.

Buildings housing gas producers are generally constructed of non-combustible materials although coal stored in and near the structures could be ignited.

Roaster Building.

The number of roasters at different plants varies from 2 to 14 depending on the type of roasting kilns and plant size. If all roasters were put out of operation, production of zinc would stop since it is impossible to smelt or leach unroasted sulfide ores.

The vertical alignment of roasting kilns must be carefully kept. A blast of sufficient force to tilt the roaster would cause the rabble arms to damage the hearths and tear the firebrick lining from the kiln. Considerable time would be required to repair this damage.

Roasting is hardly ever carried on in wooden buildings but almost always in structures of brick or sheet

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iron with steel girders.

Horizontal Retort Building.

At horizontal retort plants the actual smelting of the ores takes place in retort furnaces. Some smelters operate as many as 10 furnaces but the number depends on the type of furnace and desired plant output.

If all furnaces were knocked out production would stop, but repairing them would not be difficult or especially time-consuming.

Since hot material is handled and open flames are present, the furnace buildings are always built of non-combustible materials, usually corrugated galvanized iron.

Refining and Casting Building.

When high grade metal is desired, it is necessary to refine the metal drawn from the condensers. However, for many uses, the crude metal produced by horizontal and vertical retort plants is of sufficient purity without further treatment. This fact, coupled with the fact that if the refinery were put out of operation the crude metal could be shipped to other plants for refining, detracts from the target value of refineries.

By-products plants

Plants for the recovery of cadmium and the production of sulfuric acid are often found in connection with zinc works. While the destruction of the by-products plants would have at most only a momentary effect on zinc production, the by-products themselves may be of sufficient value to the enemy to constitute a target.

The most effective way of halting by-product production is to put the roasters and sintering machines out of operation since both the cadmium plant and the sulfuric acid plant are dependent upon them for their supply of cadmium rich dusts and SO_2 gas.

The cadmium plant equipment, consisting of leaching tanks, purification tanks, briquetting presses, retorts, and casting apparatus, is usually all housed in one building.

Mixing building.

Vertical retort plants require a very carefully prepared and mixed charge. The ore and coal are crushed and ground to the desired fineness and mixed with a liquid binder. The equipment used in this operation, crushers, grinders, hoists, mixers, and ore conveying systems, is all powered by electric motors. With the exception of the motors the equipment is of relatively sturdy construction but may be difficult to replace if destroyed.

Fire is not used in mixing, hence the building may be of any building material such as wood, reinforced concrete, brick or galvanized iron.

Vertical Retort Building.

The number of vertical retorts varies with plant size but there are usually at least eight set up in parallel. Repairing or replacing the retorts and condensers requires special silicon carbide bricks and would also require much time but unless all were put out of operation production would be merely curtailed rather than completely halted.

In addition to the retorts and condensers, the retort building contains coking ovens, hoists, and briquetting machines.

Electrolytic Cell building.

Metallic zinc in the form of sheet cathodes in produced by hundreds of electric cells set up in parallel; the number governed by the desired plant output and solution density.

Factors detracting from the target value of the electrolytic cell room are; the great number of identical units working in parallel, the non-combustible nature of the cells and their simplicity of construction.

Electrolytic cell buildings must be constructed of materials that are not greatly affected by sulfuric acid. Commonly, the floor will be of reinforced concrete, the walls of brick or concrete, and the roof of wood and tar paper with steel trusses.

Leaching and Purification.

Apparatus used in leaching the calcined ore and purifying the zinc rich solution consists of mixing tanks, settling tanks, pumps and filters, all of which are standard metallurgical equipment and therefore relatively easy to repair and replace. Many of these various units work in parallel and therefore it is necessary to destroy all units to effect total cessation of plant output.

Buildings housing the leaching and purification departments may be of any building material. Although wood is often used, inflammability is greatly reduced by the wet conditions usually existing in these buildings.

Fan Building.

Continuous operation of the blowers which transport the zinc oxide laden gases from the furnaces to the bag houses is vital to the operation of the plant. Since there are a number of electrically driven blowers set up in parallel, the most effective method of stopping them would be to damage or destroy the substation furnishing them power.

The motors and blowers may be difficult to repair but in industrial areas they could probably be readily replaced.

Zinc Oxide Furnace Building.

The zinc oxide furnace building contains a long row of furnaces, equipment to transport and charge the calcined ore and coal into the furnace, and the necessary slag disposal equipment. Incandescent charges and open flames are present in the building and consequently these buildings are never constructed of combustible materials. The large number and sturdy construction of the furnaces likewise detract from the target value of the furnace building.

Baghouses.

Flues from the blowers carry the zinc oxide laden gases to the baghouse where the oxide is filtered out and collected. Although the cotton or woolen bags are inflammable, the ever present threat of accidental fires in the baghouse has probably caused adequate fire fighting and prevention apparatus to be installed. The baghouse contents; flues, hoppers, and scores of bags, are inexpensive and readily replaceable.

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SECTION 5

SULFURIC ACID

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MANUFACTURING PROCESSES

A brief description of sulfuric acid manufacturing processes is considered necessary in view of the fact that a great many zinc plants, and to a lesser extent copper and lead plants, produce sulfuric acid from the waste gases expelled by roasters, sintering machines, and blast furnaces. These gases are otherwise worthless, and in many places are a source of great expense to the metallurgical plants owing to damage suits by those whose crops or trees are injured. Thus, not only is the sulfur dioxide nuisance avoided by converting the gases to sulfuric acid, but additional profits are realized by the smelters.

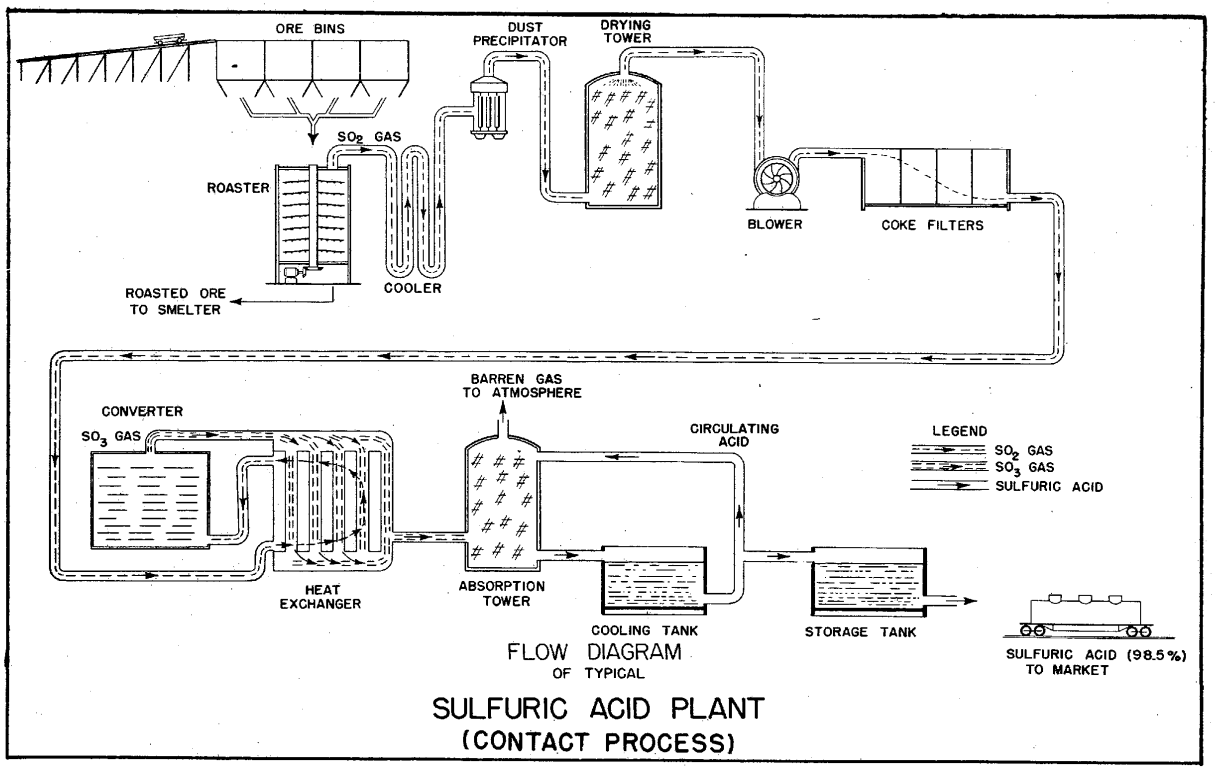
Sulfuric acid is made by mixing sulfur dioxide and water in the presence of a catalyst (the Contact process) or in the presence of oxides of nitrogen (the Chamber process.) The three principal sources of sulfur dioxide, in order of importance, are: (1) sulfur, (2) iron pyrites, (3) smelter gases. This discussion deals only with sulfuric acid plants treating smelter gases although acid plants fed by sulfur or iron pyrites are essentially the same in construction and appearance.

Smelter gases may be handled by either a "Contact" or a "Chamber" plant depending on the local and economic conditions. The chief advantage of the "Contact" process is that acid of any desired strength may be produced, while acid of not greater than 77% (60° Baume) can be made by the "Chamber" process. The operation and equipment of both types of plants are described below.

CONTACT PLANT

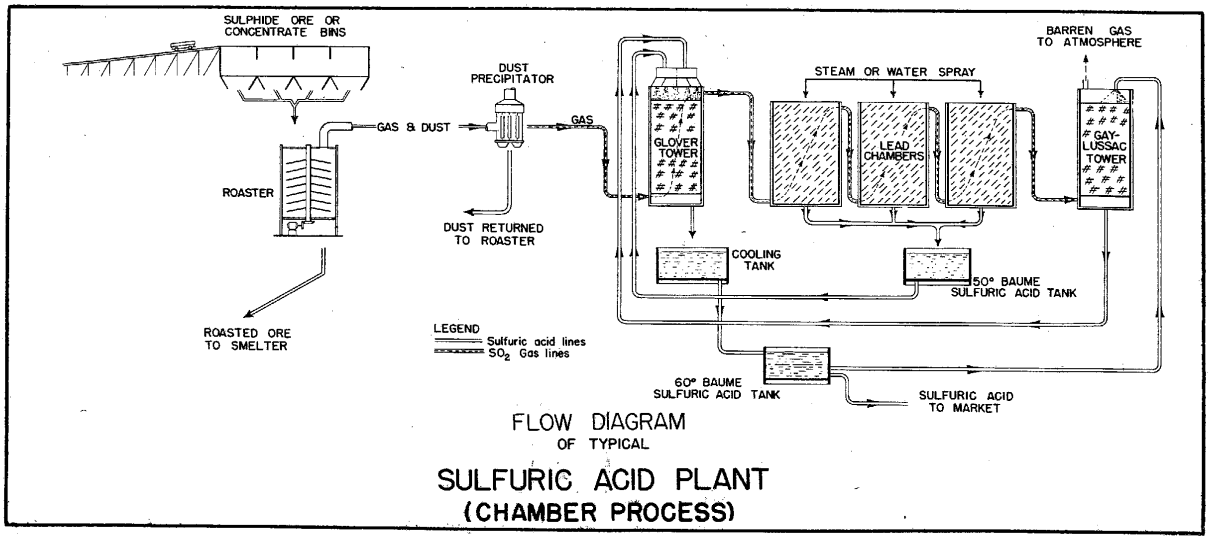
Three steps are involved in the production of sulfuric acid by the contact process: (1) cleaning and purifying the sulfur dioxide bearing smelter gases, (2) converting the sulfur dioxide to sulfur trioxide, (3) absorption of sulfur trioxide with the formation of 98.5% sulfuric acid.

Step 1 – The hot, dust laden gas drawn off the roasters, sintering machines, or blast furnaces is cooled by passing through heat exchangers or water cooled pipes prior to dust removal in a Cottrell electrostatic precipitator. Moisture is removed from the gas by sending it through acid proof brick-lined steel towers fed with concentrated sulfuric acid which is water absorbent. Following moisture removal, the gas is picked up by



FLOW DIAGRAM OF TYPICAL

SULFURIC ACID PLANT (CONTACT PROCESS)



FLOW DIAGRAM OF TYPICAL

SULFURIC ACID PLANT (CHAMBER PROCESS)

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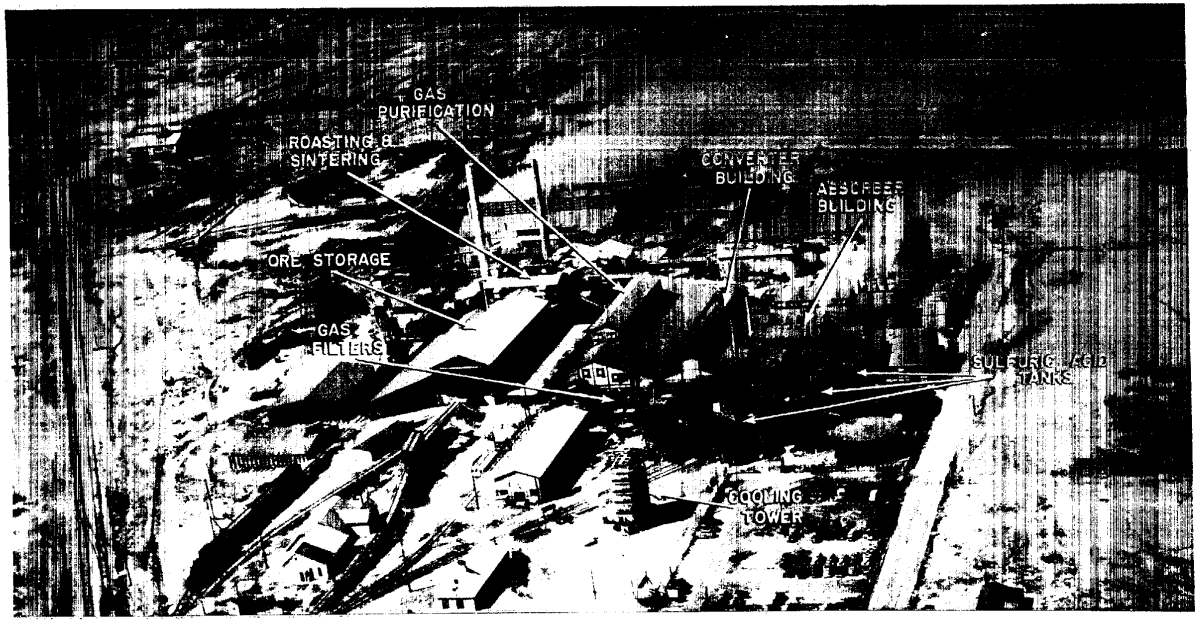
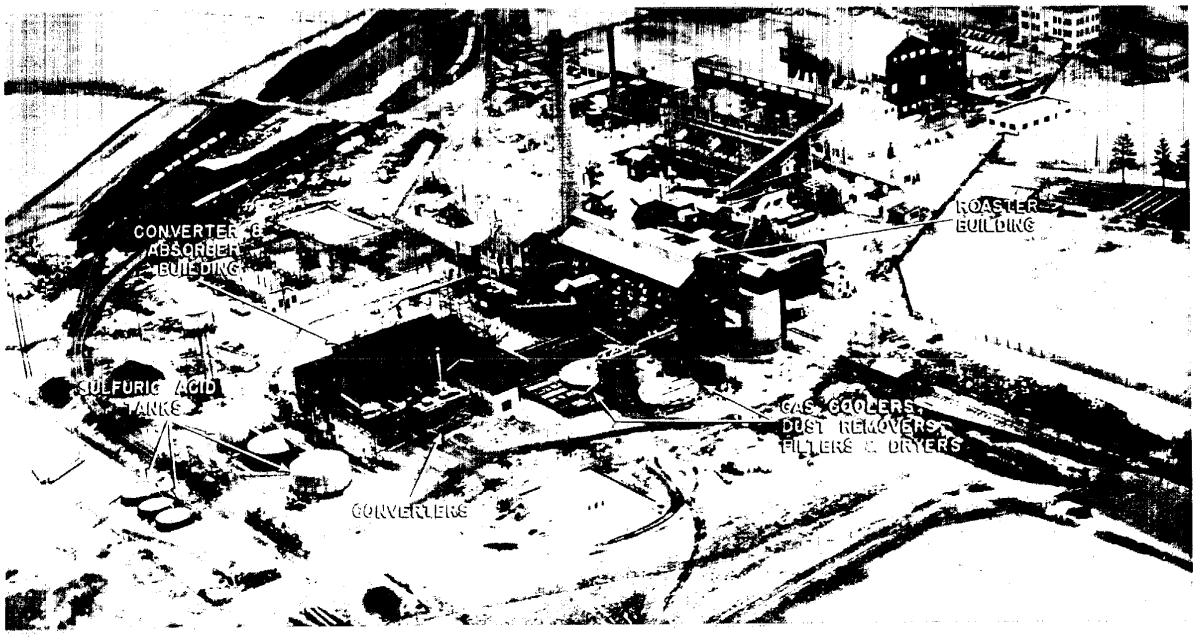


CONTACT SULFURIC ACID PLANTS AT ZINC SMELTERS



blowers and forced through coke filters which filter out any remaining dust or liquid particles.

Step 2 - The cleaned sulfur dioxide is ready, after heating, for conversion to sulfur trioxide. Conversion takes place in a vertical cylinder containing numerous shelves on which the catalyst, finely divided platinum or vanadium, is spread. The reaction taking place in the converter generates excessive heat and, therefore, the sulfur trioxide must be cooled, either by water or air coolers, to the temperature at which it can be subsequently absorbed.

Step 3 - The cooled sulfur trioxide is sent to large brick lined cylindrical steel towers, called absorbing towers. Here the actual production of sulfuric acid takes place. As the gas travels up the tower, it is met by a stream of unsaturated sulfuric acid which absorbs the sulfur trioxide with the resultant formation of 98.5% acid. The barren gas, after all sulfur trioxide has been absorbed, leaves the top of the tower and is expelled to the atmosphere. The acid flows from the bottom of the tower into a cooler and then to storage tanks from which acid is drawn for sale.

CHAMBER PLANT

Basically similar transformations are effected in the chamber process as in the contact process, i.e., the sulfur dioxide gas is first cleaned, then oxidized to sulfur trioxide, and finally absorbed by water to form sulfuric acid. The difference between the two processes lies in the materials and equipment employed to assist and control these reactions. A typical chamber plant consists of 3 principal pieces of equipment: (1) A Glover tower which is essentially a tall, square, brick chamber, 10 to 15 feet square and 30 to 40 feet high, loosely filled for most of its height with a packing of brick or tile: (2) Lead chambers which are 20 to 30 feet wide, 20 to 30 feet high, and 50 to 150 feet long constructed acid resistant sheet lead; (3) A Gay-Lussac tower, the construction and packing of which is essentially the same as that of the Glover tower. In addition there are blowers and pumps required for the transfer of gases and acid plus numerous tanks for the storage of intermediate and salable acid.

The SO_2 gas produced by the roasters and sintering

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machines is first forced through dust-catchers, usually Cottrell electrostatic precipitators, and then passes up through the Glover tower where it picks up oxides of nitrogen* and some steam. From the Glover tower the gas stream is carried to the lead chambers, where it is mixed with water spray resulting in the formation of sulfuric acid. The barren gas leaving the chambers, before being expelled to the atmosphere, is sent to a Gay-Lussac tower where the oxides of nitrogen are recovered for re-use in the Glover tower.

The acid produced in the lead chambers is relatively weak and consequently must be partially concentrated. To accomplish this, the acid is pumped to the top of the Glover tower where the hot incoming SO_2 gas evaporates some of the water in the acid as it trickles through the packing of the tower. The 60° Baume acid leaving the tower flows into cooling tanks before being transferred to the finished product storage tanks.

*NOTE: The oxides of nitrogen have a function not unlike that of a catalyst in that they aid the reaction without being consumed themselves. Periodically the supply of these oxides must be replenished since some escape with the barren gas leaving the Gay-Lussac tower.

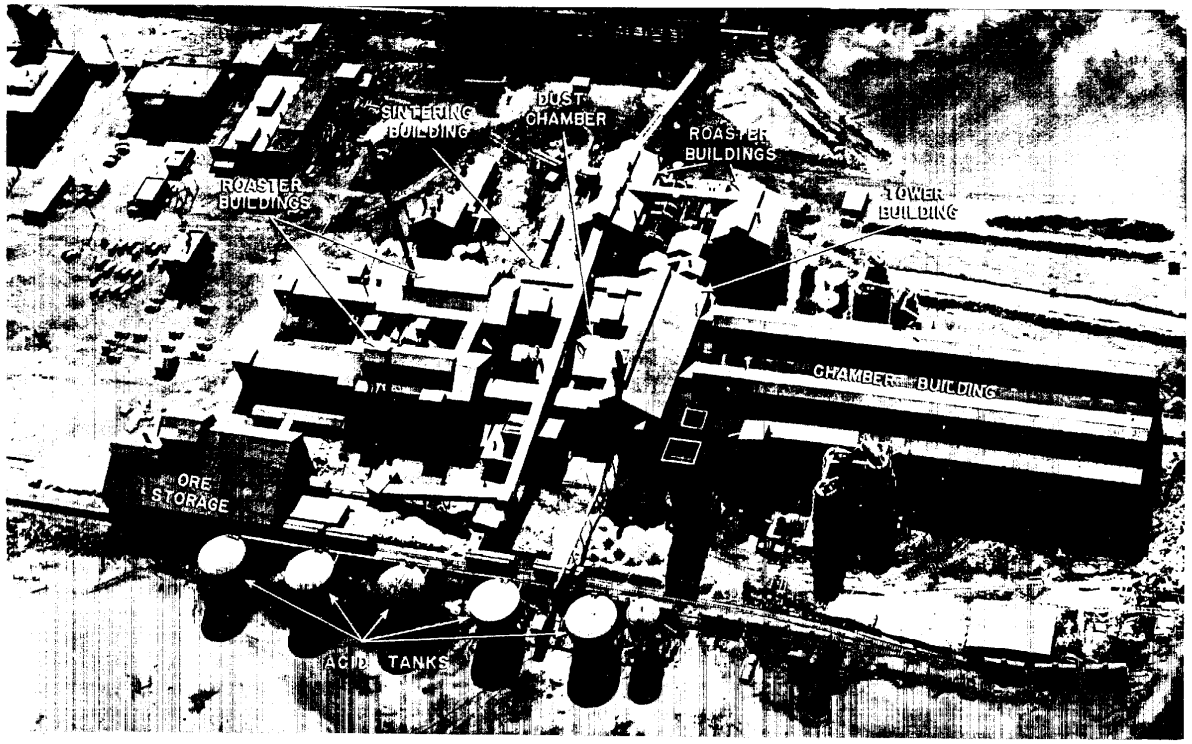
DISTINGUISHING FEATURES

Sulfuric acid plants, when present at smelters, are usually located adjacent to the roasting and sintering buildings and always connected to them by large flues. Storage tanks, commonly 5 or 6 in number, are always required and their presence constitutes a valuable recognition feature of acid plants. Tank cars or tank barges at a smelter provide additional evidence of the existence of a sulfuric acid plant.

In most cases the special features of the two types of acid plants make it possible to determine from aerial photographs which process is being employed. The characteristics of the component parts of the two plants are treated below.

CONTACT PLANT

In general a contact acid plant gives a "cluttered up" appearance due to the many cooling towers, heat exchangers, scrubbing towers, filtering equipment, converters, absorbing towers, storage tanks, and interconnecting pipelines. Sometimes part of this apparatus will be housed, in which case the gas purification equip-



CHAMBER SULFURIC ACID PLANTS AT ZINC SMELTERS

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DISTINGUISHING FEATURES OF SULFURIC ACID PLANTS—VULNERABILITY

ment will be enclosed in the building nearest the ore roasters, the converters in the next adjoining building, and the absorbers in the last structure. Gable roofs with monitors for ventilation are common to each of the three buildings, but the absorber building is unique in having stacks. Another clue to the recognition of the absorber building is the presence of large acid storage tanks nearby.

CHAMBER PLANT

In contrast to the maze of pipelines, cylinders, and towers seen at a contact plant, the only unenclosed units at a chamber plant are the storage tanks and in rare cases the Glover and Gay-Lussac towers.

The buildings comprising a plant of this type can be readily identified by their size, height, and position with respect to the source of the gas. Dust catchers are housed in a small low building which is connected to the ore roaster building by a flue. The tower building, enclosing the Glover and Gay-Lussac towers, is of moderate length, narrow, and is unmistakable by being the tallest building of the plant and having one or two short stacks. The chamber building, a long, wide building with a twin gable roof, comprises at least 70% of the total floor area of the sulfuric acid plant. Normally these three buildings will adjoin each other with the tower building located between the dust catcher building and the chamber building.

Plants of major importance will have not just one of these units, but two or three identical units operating in parallel. Each unit will be complete in itself and will function more or less independently.

VULNERABILITY

Sulfuric acid plants can generally be considered better high explosive than incendiary bomb targets since most of the plant equipment must be acid resistant and consequently is constructed of such non-combustible materials as lead and brick. The blast effect of high explosive bombs may cause considerable damage to brick and brick-lined towers.

Acid production would be immediately stopped by destruction of the pumps, blowers, or their source of power. Likewise, destruction of or damage to absorption, Glover, or Gay-Lussac towers would temporarily halt production. None of this equipment could be considered difficult to replace but repairing or rebuilding some units would be time consuming.

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SECTION 6

COMMERCIAL USES OF COPPER, LEAD AND ZINC

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COMMERCIAL USES OF COPPER, LEAD, AND ZINC

INTRODUCTION

The ultimate uses of copper, lead, and zinc in the finished products of commerce are extremely varied - especially so because final products are derived from both metals and compounds of the elements. In the world markets of 1938 copper, lead, and zinc (as measured by weight) ranked tops respectively in the sale of principal non-ferrous metals; aluminum ranked fourth. It is likely that the tremendous increase of aluminum production for the manufacture of war time aircraft has altered this non-ferrous metals relationship today, but production of copper, lead, and zinc is vital to war needs too and has accordingly increased greatly.

It is not possible to describe all of the commercial uses of these metals in this short section, nor is it wise since the photo interpreter is interested only in manufacturing processes that take place in plants identifiable from the air. For these reasons only important war time uses are considered here.

SUMMARY OF USES

Copper: The important uses of copper are as wire and cable, as sheeting and stripping, as tubing, and as a base for alloys like brass and bronze. It has been estimated that Japanese stock piles of copper are currently being divided:

50% for ammunition
20% for electric power transmission, communications, etc.
10% for marine uses
10% for air and land transport, and
10% for other industrial uses.

Lead: Lead is used commercially (1) in the form of the metal, (2) as an alloy with other metals, and (3) in various chemical compounds. In the form of the metal its chief uses are as pipe for conveying water and corrosive solutions, as covering for electric cables, and as sheets for lining the acid chambers and vats of chemical industries. Lead alloys include type metal, shot, solder, and casting metals; while lead compounds consist of white lead, red lead, litharge, and lithopone. In Japan war time uses of lead are estimated approximately as follows;

30% for lead pipes and cable,
30% for bullets and other military uses,
25% for battery plates,
15% for type-metal, solder, alloys, and sundry uses.

Zinc: Zinc is used to supplement copper in brass, to add protective (galvanized) surfaces to products fabricated from other metals, to make die castings, to mix in paint etc. as pigment, to aid in the desilverization of lead, and to serve a number of special needs in the form of rolled strip zinc. In peacetime over 42% of the zinc produced is used for galvanizing, with brass, die castings, and rolled zinc following in respective order of importance. In war time, however, zinc used in brass production takes precedence over everything else. This fact is strikingly illustrated by the following estimate of present day Japanese zinc allocations:

70% for cartridge brass
15% for galvanized sheets, paints, electrical apparatus, aircraft, alloys, castings, brass pipes, tubes, and parts.
13% for rolled sheets, screens, wire, chemical uses etc.
2% for civilian needs.

PLANTS USED FOR COMMERCIAL PRODUCTION

The buildings and equipment used to manufacture commercial copper goods are ordinarily organized in plant units that produce wire and cable, sheets and strips, tubing, alloys, or finished products. Compared with basic smelting and refining units these plants are for the most part both small and numerous.

The buildings and equipment used to manufacture commercial lead and zinc goods may take the form of small separate complexes, but more often they are arranged in units attached to other types of plants. Thus processes like galvanizing are usually carried on at the plant site where the material to be galvanized is manufactured - and the manufacture of products like white lead and rolled zinc is carried on in small units built as additions to lead and zinc refineries.

The important manufacturing operations to be understood in connection with the production of finished goods from copper, lead, zinc, and their alloys are therefore wire and cable fabrication, tube manufacturing sheet and strip rolling. These operations are carried on in a number of different types of plants, each with its own special characteristics and each developed to meet the varied demands of its individual owner.

Because wire, sheet, and tube mills are so differently laid out and so differently associated with other types of operations, it is impossible to prepare any valid listing of distinguishing features that will always be applicable for use in identification. Nevertheless, the photo interpreter may derive some value from a brief consideration of wire and cable, tubing and sheet mills in terms of buildings, equipment, and processes used at each.

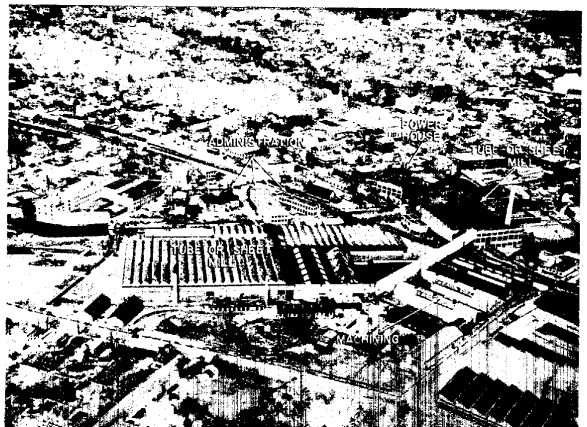
SUMMARY OF USES

Generally sheet, tube, and wire mills buildings are standard industrial structures built either with saw toothed roofs or with gable roofs topped by monitor lights. The equipment contained within each type varies from heavy machinery to light and is serviced by overhead cranes set in the wider bays of main buildings. Drawing and finishing machinery installed in wire and cable buildings tends to be considerably lighter than the rolling mills and extruders of sheet and tube plants. This together with the fact that inflammable stores (cotton, rubber, lacquer, etc.) for finishing operations are usually present at wire mills makes this type of plant more vulnerable to damage than sheet or tube mills.

It should be noted that although copper and brass rolling mills operate on the same principle as steel rolling mills, they use lighter equipment and process smaller shapes. A more apt comparison can be made between copper and brass, and aluminum and magnesium mills.

The principal buildings and processing stages used in the manufacture of wire and cable, tubing, sheets, and brass are listed on the following pages:

TYPICAL BRASS MILL



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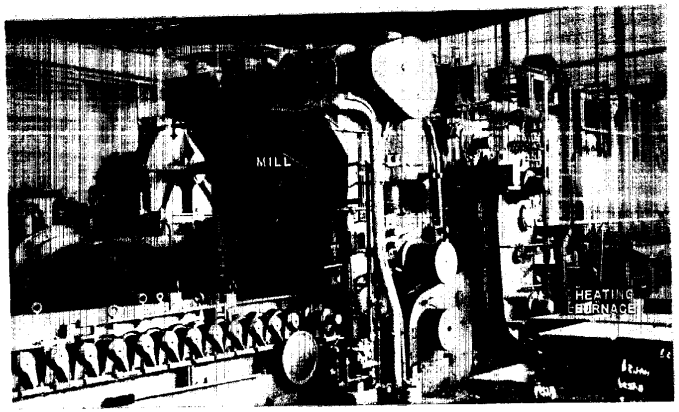
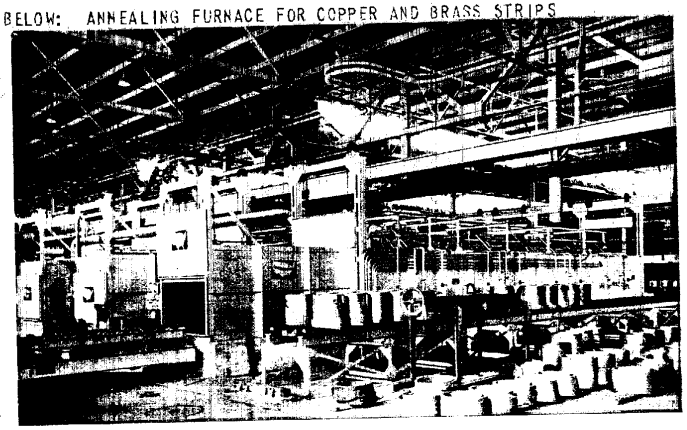
COMMERCIAL USES OF COPPER, LEAD, AND ZINC

SHEET MILLS — TUBE MILLS

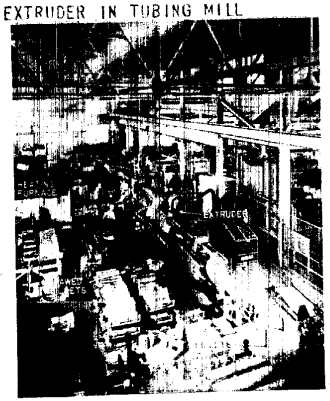


ABOVE: SHEET ROLLING MILL AT A BRASS PLANT

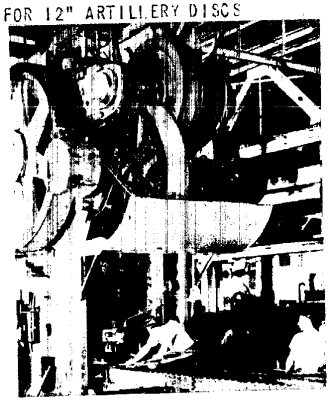
BELOW: ANNEALING FURNACE FOR COPPER AND BRASS STRIPS



EXTRUDER IN TUBING MILL



A LARGE BLANKING PRESS FOR 12" ARTILLERY DISCS



SEQUENCE OF OPERATIONS	SHEET MILLS TYPE OF BUILDING GENERALLY USED	REMARKS
(1) Cakes are received by rail or water from copper refinery and stored at end of rolling mill building.		At some plants cakes are stored in shedlike structures separate from mill building.
(2) They are then charged into a brick furnace and heated white hot.		
(3) Hot cakes are removed periodically to rolling mills where they are passed back and forth through rollers until desired dimensions are reached.	Steps 1 - 6 are usually housed in a single multibayed structures possessing either saw toothed roof or gabled roof with monitor light.	Cake heating and annealing furnaces may be either electric or burner fired; burner fired furnaces may or may not possess stacks that project through the mill building roof.
(4) Completed sheets or strips are cooled by water bath or spray.		
(5) Cooled sheet or strip next scalped of black oxide surface formed during cooling.		
(6) Scalped product is passed through annealing or temporizing furnace and then washed in dilute acid pickling tanks.		
(7) Completed sheets are cut to size or sent to stamping presses and finishing machines for manufacture of final products.	Step 7 may be carried on in a corner of rolling mill building or in separate heavily constructed multi-floored machine building.	
	TUBE MILLS	
(1) Billets received by rail or water from refinery and stored either in sheds or at end of tubing building.		Raw material for tubes is sometimes hollow cast; hollow cast billets don't require extrusion and can be drawn directly.
(2) Billets sawed to length and heated in rotary burner-fired furnace.		
(3) Heated billets forced into shape of tube by hammering through the die of a compressed air extruder.	All processes of tubing manufacture are usually carried on in a single multi-bayed structure possessing either a saw toothed roof or a gable roof with monitor lights.	
(4) Short extruded tube		

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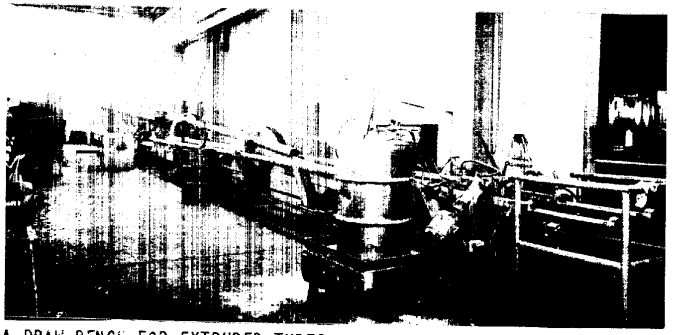
TUBE MILLS

SEQUENCE OF OPERATIONS	TYPE OF BUILDING GENERALLY USED	REMARKS
pointed and stretched to required length by drawing through dies on a number of draw benches.		
(5) Between draws, tubes cut to length and washed in dilute acid pickling tanks.		
(6) After drawings, tubes tempered in an annealing furnace; then tested straightened, packed, and shipped.		

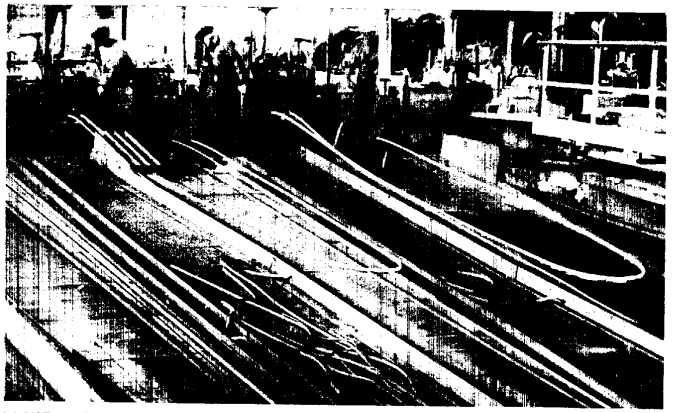
WIRE MILLS

(1) Raw materials received in form of refined copper wire bars (for wire drawing) - lead pigs, cotton bales, rubber, lacquer, etc. (for finishing) and stored as noted in column three.		Wire bars usually stored in open - finishing materials in separate storage building or on special floors of finishing and insulating buildings.
(2) Wire bars are heated in brick furnaces and then rolled white hot into rods by successive passes through three sets of rolling mills (rough, intermediate, and finishing). Rods wound on machines into coils and then washed in dilute acid pickling tanks.		
(3) Coiled rods are drawn on machines through successive dies in successive operations until diameters are reduced to required wire sizes.	Steps 2 - 5 usually carried on in large wide bayed and well lighted rectangular buildings.	
(4) Drawn wire is then passed through an annealing furnace to impart softness and pliability.		
(5) When annealed, some wires go to cable stranding machines where they are braided into cable.		
(6) Annealed wire and cable	Wire and cable finishing	

COMMERCIAL USES OF COPPER, LEAD, AND ZINC

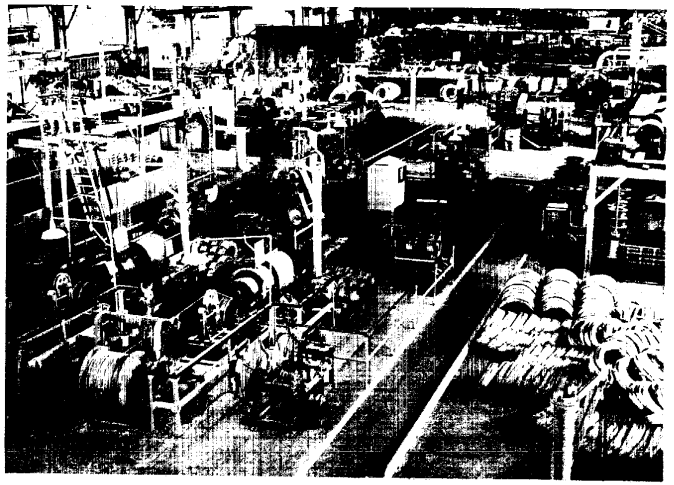


A DRAW BENCH FOR EXTRUDED TUBES



ABOVE: ROLLING WIRE RODS

BELOW: WIRE DRAWING AND CABLE STRANDING EQUIPMENT



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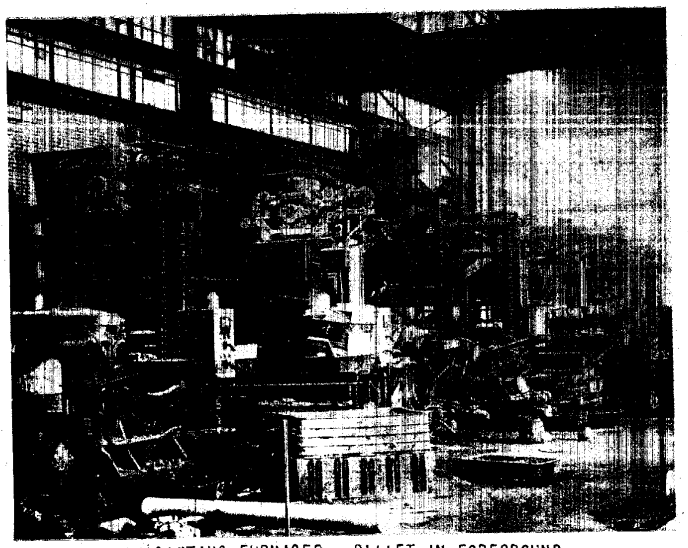
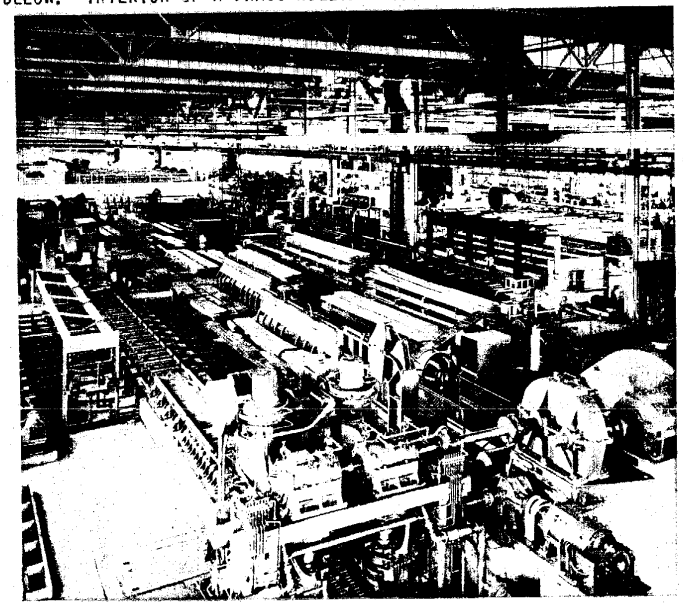
COMMERCIAL USES OF COPPER, LEAD, AND ZINC

WIRE MILLS —— BRASS MILLS



ABOVE: ALLOY CASTING FURNACES - BILLET IN FOREGROUND

BELOW: INTERIOR OF A BRASS ROLLING MILL



SEQUENCE OF OPERATIONS	WIRE MILLS TYPE OF BUILDING GENERALLY USED	REMARKS
then sent to finishing rooms where it is insulated with lead, silk, lacquer, rubber, paraffin, etc.	usually carried on either in a well lighted, though somewhat smaller, rectangular structure separate from the wire mill, or in small rectangular sections constructed as connecting additions to mill.	
(7) Completed wire and cable rolled on reels - packed and stored for shipping.		
(8) Throughout entire process all wire is subjected to careful testing and inspection.	Section of building for lacquer finishing of wire may posses a number of small ventilators arranged in a closely spaced pattern on its roof. Testing and inspection may be carried on in other small connecting buildings.	
	BRASS MILLS	
(1) Raw materials received include copper and zinc ingots, sheared cathodes, scrap, and (if other alloys are also made) nickle slugs, tin, etc.	Raw materials stored in long rectangular metal receiving building serviced by railway. Usually located adjacent to casting building.	
(2) Charge made up in proper proportions for casting furnace.	Charges made up in special room of metal receiving or casting building.	
(3) Charge melted in carbon anode, electric induction, or nearly obsolete pit-fired casting furnaces; then cast into cakes or billets.	Casting furnaces located in special structures attached to metal receiving building or established at end of rolling and tubing buildings.	Initial charge of carbon-anode furnaces pre-heated in special gas fired furnace. If burner fired furnaces are used in place of electric furnaces stacks may assist in identifying casting building. Old pit-fires consist mainly of a hole in the ground serviced by a number of stacks.
(4) Cakes and billets scalped; billets sawed to length.		
(5) Scalped shapes sent to cake heating or billet heating furnaces where they begin cycle of operations required to produce tubing or sheeting (as listed above).		

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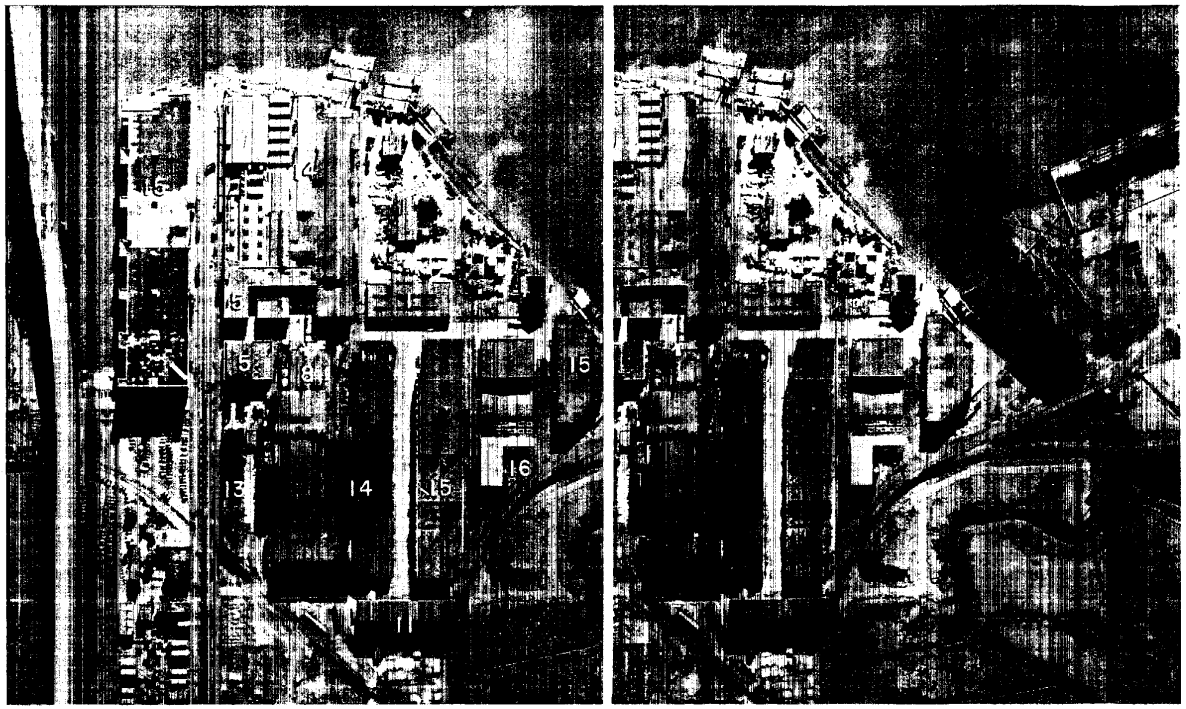
COMMERCIAL USES OF COPPER, LEAD, AND ZINC (STUDY PHOTOS)

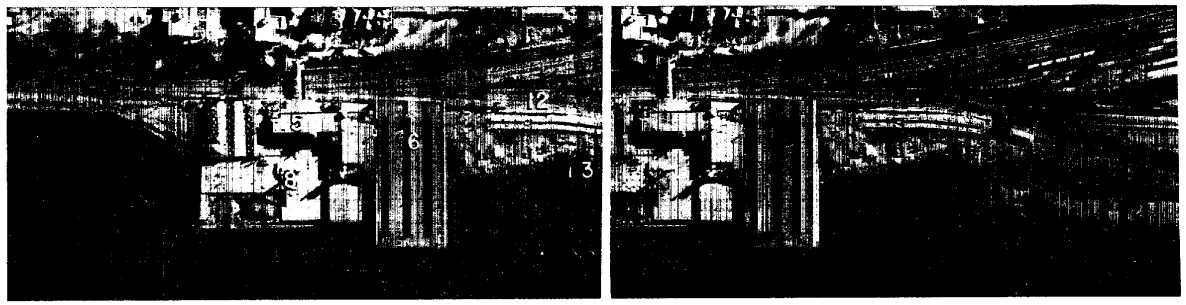
HASTINGS WIRE AND CABLE MILL

1. STORAGE OF FINISHING MATERIALS
2. FINISHING MACHINES
2a. WAX PLANT
2b. FUEL TANKS
3. CABLE REEL STORAGE
4. ASPHALT PLANT
5. ADMINISTRATION BUILDING
5a. FINISHING - RUBBER WIRE
6. WIRE AND CABLE MILL
7. WIRE FINISHING
8. POWER PLANT
9. MACHINE SHOP
10. ROD ROLLING MILL
11. CARPENTER SHOP
12. WIRE BAR STORAGE
13. SHIPPING AND RECEIVING BUILDING
14. PRIMARY PROCESSING UNITS (ROD ROLLING, WIRE DRAWING, CABLE STRANDING, ETC.)
15. FINISHING BLDGS. AND MANUFACTURING OF PARTS FOR ELECTRICAL APPLIANCES



ABOVE: BAYWAY WIRE AND CABLE MILL

BELOW: YONKERS WIRE AND CABLE MILL



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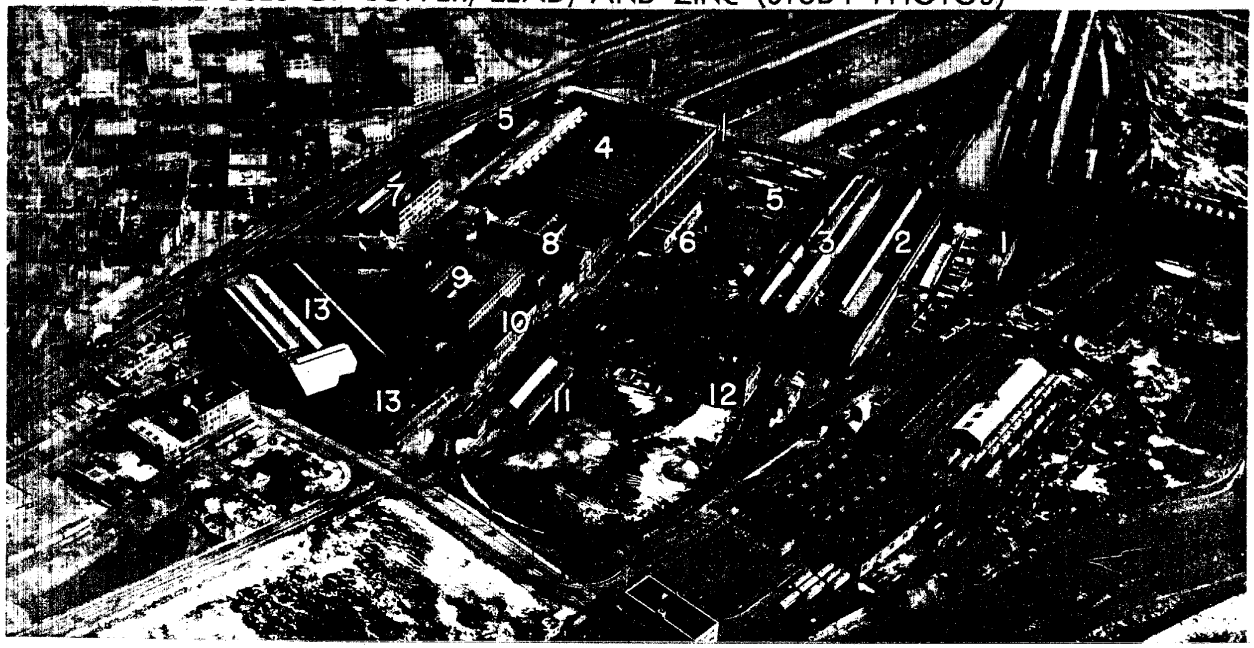
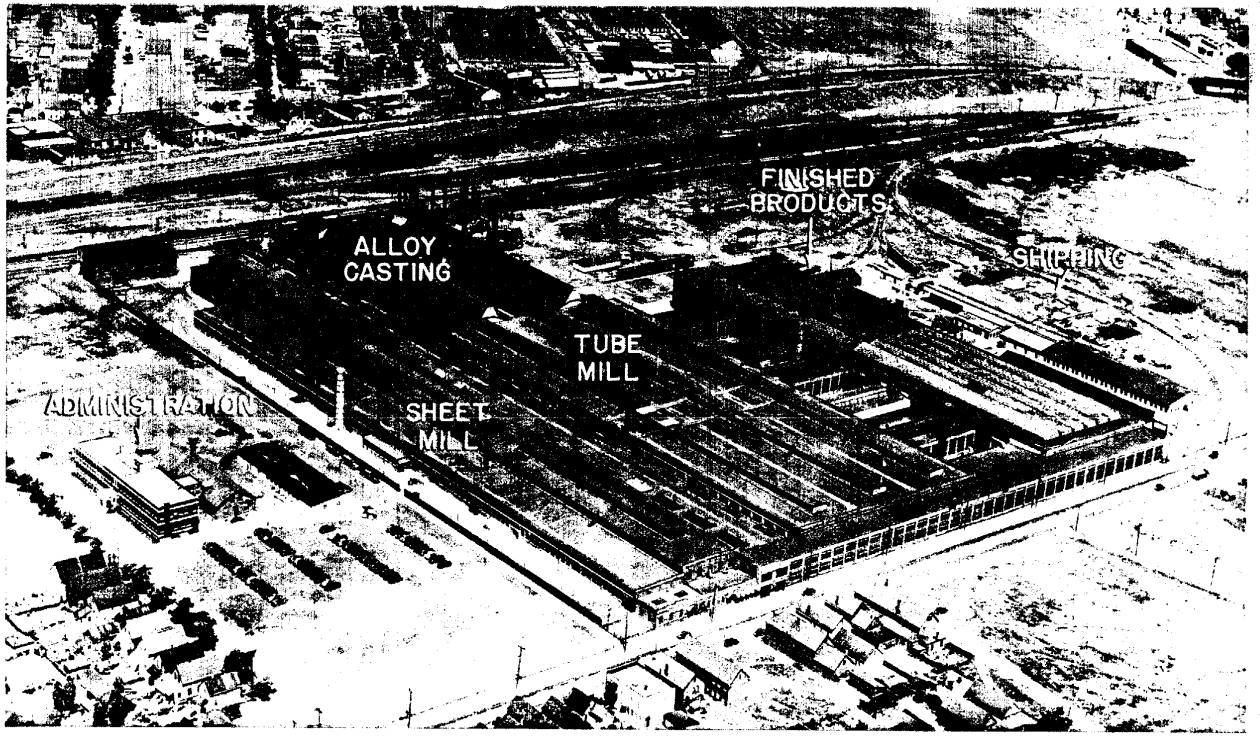


SHEET, ROD AND WIRE MILLS



1. COAL STORAGE
2. METAL STORAGE BUILDING
3. CASTING SHOP
4. ROLLING SHEET MILL BUILDINGS (3 ROLLS)
5. GARAGES
6. STORAGE SHED
7. MECHANICAL BUILDING
8. MACHINERY, PACKING AND STORAGE
9. MANUFACTURING BUILDING
10. SHOPS
11. FREIGHT SHED
12. POWER HOUSE
13. ROD AND WIRE MILL

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